Implementing condition monitoring using the AVEVA PI System to drive Condition-Based Maintenance

Meridian Energy at AVEVA World San Francisco

William Herewini and Saif Fawzi
Presentation Agenda

Who are we?
Our business challenge
Our data pipeline
Use cases
Results and benefits
What’s next?
Who are we?

Aotearoa/New Zealand's largest energy generator with over 2800 MW of installed capacity equating to approx. 30% of the country’s electricity

100% renewable generation – Wind, Water and Sun
- 7 hydro stations
- 5 wind farms with 2 new underway
- Grid-scale Battery Energy Storage Systems (BESS) and solar array underway

We retail electricity to more than 363,000 customers (or about 15% of household and business) across Aotearoa through our Meridian and Powershop brands.
Who are we?

Our purpose – Clean energy for a fairer and healthier world

More than just power – doing our bit to help drive sustainability for ourselves and our customers

• Fleet electrification
• Community Decarbonisation
• KidsCan
• Kākāpō Recovery
• Forever Forests
Who are we?

The power to make a difference through data

Improve processes from a routine-based maintenance approach to a data informed condition-based maintenance approach

Why?
Make life easier for our on-site teams to do their jobs effectively

Improve asset health

Do our bit to keep the lights on in Kiwi homes and Aotearoa/New Zealand powered through the cold winter months
Our Business Challenge

Problem
• Lack of visibility into our generating assets
• Requiring plant outages and routine maintenance to investigate the degradation of our generating assets
• Outage flexibility becoming less frequent due to constraints from market demand

Goal
• Meridian Energy would like to optimise resource usage through condition-based maintenance

The AVEVA PI System ecosystem was crucial for this
Our Data Pipeline

AVEVA PI System collects data points from our assets and stores them within our PI Data Archive.

AVEVA PI Asset Framework builds analytical models to format and contextualise data.

AVEVA PI Vision and Dimension Software’s Asset Intellect constructs platform to collate and present relevant information from various data sources.

White Hill Wind Farm, Southland
### Category: Configuration

<table>
<thead>
<tr>
<th>Configurable Values</th>
<th>Value</th>
<th>Description</th>
<th>Setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>MANAPOURI POWER STATION</td>
<td>0</td>
<td>Site Description - Site Unit</td>
<td></td>
</tr>
<tr>
<td>Element Code</td>
<td>MAN_01</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minimum Custom Range 1 Threshold High</td>
<td>80 MW</td>
<td>High threshold for running range between 65-80 MW</td>
<td></td>
</tr>
<tr>
<td>Minimum Custom Range 1 Threshold Low</td>
<td>65 MW</td>
<td>Low threshold for running range between 65-80 MW</td>
<td></td>
</tr>
<tr>
<td>Overload Threshold</td>
<td>122 MW</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum Running High</td>
<td>70 MW</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum Running Low</td>
<td>45 MW</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tag Name</td>
<td>MAN_01</td>
<td>MANAPOURI UNIT 1</td>
<td></td>
</tr>
<tr>
<td>Transition Threshold High</td>
<td>0 MW</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transition Threshold Low</td>
<td>0 MW</td>
<td></td>
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</tr>
<tr>
<td>Unit Name</td>
<td>MAN_01</td>
<td>MANAPOURI UNIT 1</td>
<td></td>
</tr>
</tbody>
</table>

### Category: Tags

- CB Closed Tag: 0
- CB Open Tag: 0
- Custom Range 1 Tag: 0
- Short Started Time Tag: 0
- Short Stopped Time Tag: 0
- Transition Range Tag: 0

### Category: Input

- Generator Start Point MW: 0 MW
- Generator MW: 0 MW
- Start PE: 0
- Stop PE: 0
- TWI Status: 0
- Unit CB Status: Open
- Unit CB: 1
- Unit Speed: 0.0 %
- Unit Symbol Status: Tripped

### Category: Output
Use Cases

Hydro Unit Stopping Sequence Analysis

Hydro Unit Fatigue Monitoring
Hydro Unit Stopping Sequence Analysis

Problem

• Hydro generation units not stopping as expected leading to forced outages

• Loss of potential generation during outage period

• Uncertainty of root cause
  • Wicket gate failure
  • Degrading brake pads
Hydro Unit Stopping Sequence Analysis

Approach
• Use time-series data collected via AVEVA’s PI system with PI Asset Framework and PI Vision
• Create event frames for each unit’s stopping sequence
• Perform analytics on raw data to generate contextualised information
• Present information using PI Vision
<table>
<thead>
<tr>
<th>Name</th>
<th>Default Value</th>
<th>Settings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Braking Status</td>
<td>0</td>
<td>%{Server}%STATUS:%Element Code%MKASOG03100M</td>
</tr>
<tr>
<td>Headwater Level</td>
<td>0 m</td>
<td>%{Server}%ANALOG:MAN SSSTN HWL</td>
</tr>
<tr>
<td>Rotate Status</td>
<td>0</td>
<td>%{Server}%STATUS:%Element Code%rotate</td>
</tr>
<tr>
<td>Stopped Status</td>
<td>0</td>
<td>%{Server}%STATUS:%Element Code%STOPPED</td>
</tr>
<tr>
<td>Stopping Status</td>
<td>0</td>
<td>%{Server}%STATUS:%Element Code%STOPPING</td>
</tr>
<tr>
<td>Tailwater Level</td>
<td>0 m</td>
<td>%{Server}%ANALOG:MAN SSSTN HWL</td>
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<tr>
<td>Tripped Status</td>
<td>(SV) Tripped</td>
<td>%{Server}%STATUS:%Element Code%TRIPPED</td>
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<td>Unit Circuit Breaker</td>
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<td>%{Server}%STATUS:%Element Code%UNDET_CB</td>
</tr>
<tr>
<td>Unit Speed</td>
<td>0 %</td>
<td>%{Server}%ANALOG:G%Element Code%SPEED</td>
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</table>

<table>
<thead>
<tr>
<th>Name</th>
<th>Default Value</th>
<th>Settings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brake Status Flag</td>
<td>0</td>
<td>%{Server}%AF%Element Code%MK_BRAKE_FLAG</td>
</tr>
<tr>
<td>Braking Duration</td>
<td>0.00 s</td>
<td>%{Server}%AF%Element Code%MK_BRAKE_DUR</td>
</tr>
<tr>
<td>Wet Head</td>
<td>0 m</td>
<td>%{Server}%AF%Element Code%MK_NET_HWL</td>
</tr>
<tr>
<td>Ramp Down Duration</td>
<td>0.00 s</td>
<td>%{Server}%AF%Element Code%MK_RAMP_DWN_DUR</td>
</tr>
<tr>
<td>Stop Initiate Duration</td>
<td>0.00 s</td>
<td>%{Server}%AF%Element Code%MK_STOP_INITIATE_DUR</td>
</tr>
<tr>
<td>Total Stop Duration</td>
<td>0 s</td>
<td>%{Server}%AF%Element Code%MK_TOTAL_STOP_DUR</td>
</tr>
<tr>
<td>Wicket Gate Position</td>
<td>0</td>
<td>%{Server}%AF%Element Code%MK_WGGate_POS</td>
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</table>

<table>
<thead>
<tr>
<th>Name</th>
<th>Default Value</th>
<th>Settings</th>
</tr>
</thead>
<tbody>
<tr>
<td>AvgBraking3mo</td>
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<td>%{Server}%AF%Element Code%MK_BRAKE_DUR_3MO_AVG</td>
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<tr>
<td>AvgRampDown3mo</td>
<td>0 s</td>
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<td>0.00 s</td>
<td>%{Server}%AF%Element Code%MK_STOP_INITIATE_DUR_MEDIAN</td>
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<tr>
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<td>%{Server}%AF%Element Code%MK_BRAKE_DUR_3MO_MEDIAN</td>
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<tr>
<td>StopInitiate50Percentile3mo</td>
<td>0.00 s</td>
<td>%{Server}%AF%Element Code%MK_STOP_INITIATE_DUR_MEDIAN</td>
</tr>
</tbody>
</table>
### Example Element:
**Meridian Energy/Wyndham/AMAN/MAN06 - MANAPURU UNIT 6/MAKA - CASING INCLUDING STATOR, ROTOR AND COOLERS/MKA60 - STOPPING SEQUENCE**

#### Generation Mode: Explicit Trigger

<table>
<thead>
<tr>
<th>Name</th>
<th>Expression</th>
<th>True for</th>
<th>Severity</th>
<th>Output Attribute</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Start Triggers</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>StopInitiated</td>
<td>'Stopping Status' = 1 and 'Unit Speed' &lt;&gt; 0 and 'Unit Circuit Breaker' &lt;&gt; &quot;Closed&quot;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>End Triggers</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EndTrigTime</td>
<td>'Unit Speed' &lt; 0.05 OR 'Stopping Status' &lt;&gt; 1</td>
<td></td>
<td></td>
<td></td>
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</table>

#### Outputs at close

<table>
<thead>
<tr>
<th>Metric</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>TotalDuration</td>
<td>PrevVal('Total Stop Duration', &quot;&quot;)</td>
</tr>
<tr>
<td>NetHead</td>
<td>'Net Head'</td>
</tr>
<tr>
<td>StopInitiateDuration</td>
<td>PrevVal('Stop Initiate Duration', &quot;&quot;)</td>
</tr>
<tr>
<td>RampDownDuration</td>
<td>PrevVal('Ramp Down Duration', &quot;&quot;)</td>
</tr>
<tr>
<td>BrakingDuration</td>
<td>PrevVal('Braking Duration', &quot;&quot;)</td>
</tr>
<tr>
<td>UnitName</td>
<td>'Unit Name'</td>
</tr>
<tr>
<td>TagOfName</td>
<td>'Tag Name'</td>
</tr>
<tr>
<td>WicketGatePos</td>
<td>'Wicket Gate Position'</td>
</tr>
<tr>
<td>UnitSpeed</td>
<td>'Unit Speed'</td>
</tr>
<tr>
<td>TailwaterLevel</td>
<td>'Tailwater Level'</td>
</tr>
</tbody>
</table>

#### Advanced Event Frame Settings...
### Values of Last Stop

<table>
<thead>
<tr>
<th>Unit</th>
<th>Stop Initiate Duration</th>
<th>Stop Initiate Duration</th>
<th>Stop Initiate Duration</th>
<th>Stop Initiate Duration</th>
<th>Stop Initiate Duration</th>
<th>Stop Initiate Duration</th>
<th>Stop Initiate Duration</th>
</tr>
</thead>
</table>

### 3 Month Averages

<table>
<thead>
<tr>
<th>Unit</th>
<th>AvgStopInitiate3mo</th>
<th>AvgStopInitiate3mo</th>
<th>AvgStopInitiate3mo</th>
<th>AvgStopInitiate3mo</th>
<th>AvgStopInitiate3mo</th>
<th>AvgStopInitiate3mo</th>
<th>AvgStopInitiate3mo</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>12:00:00 AM</td>
<td>22/09/2023</td>
<td>4/10/2023</td>
<td>4/10/2023</td>
<td>4/10/2023</td>
<td>4/10/2023</td>
<td>4/10/2023</td>
</tr>
<tr>
<td>2</td>
<td>12:00:00 AM</td>
<td>12:00:00 AM</td>
<td>12:00:00 AM</td>
<td>12:00:00 AM</td>
<td>12:00:00 AM</td>
<td>12:00:00 AM</td>
<td>12:00:00 AM</td>
</tr>
<tr>
<td>3</td>
<td>12:00:00 AM</td>
<td>12:00:00 AM</td>
<td>12:00:00 AM</td>
<td>12:00:00 AM</td>
<td>12:00:00 AM</td>
<td>12:00:00 AM</td>
<td>12:00:00 AM</td>
</tr>
<tr>
<td>4</td>
<td>12:00:00 AM</td>
<td>12:00:00 AM</td>
<td>12:00:00 AM</td>
<td>12:00:00 AM</td>
<td>12:00:00 AM</td>
<td>12:00:00 AM</td>
<td>12:00:00 AM</td>
</tr>
<tr>
<td>5</td>
<td>12:00:00 AM</td>
<td>12:00:00 AM</td>
<td>12:00:00 AM</td>
<td>12:00:00 AM</td>
<td>12:00:00 AM</td>
<td>12:00:00 AM</td>
<td>12:00:00 AM</td>
</tr>
<tr>
<td>6</td>
<td>12:00:00 AM</td>
<td>12:00:00 AM</td>
<td>12:00:00 AM</td>
<td>12:00:00 AM</td>
<td>12:00:00 AM</td>
<td>12:00:00 AM</td>
<td>12:00:00 AM</td>
</tr>
<tr>
<td>7</td>
<td>12:00:00 AM</td>
<td>12:00:00 AM</td>
<td>12:00:00 AM</td>
<td>12:00:00 AM</td>
<td>12:00:00 AM</td>
<td>12:00:00 AM</td>
<td>12:00:00 AM</td>
</tr>
</tbody>
</table>
### Values of Selected Stop

<table>
<thead>
<tr>
<th>Event</th>
<th>Start Time</th>
<th>End Time</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>3:18:06s</td>
<td>21/03/2023 1:33:18 pm</td>
<td>21/03/2023 1:57:05 pm</td>
<td>23m 48s</td>
</tr>
<tr>
<td>Stop Event 2023-03-07 11:09:18 am</td>
<td>9 18 042</td>
<td>7/03/2023 11:09:18 am</td>
<td>7/03/2023 12:45:43 pm</td>
</tr>
<tr>
<td>Stop Event 2023-02-20 05:00</td>
<td>6:58:193</td>
<td>20/02/2023 5:05:58 am</td>
<td>20/02/2023 5:50:38 am</td>
</tr>
</tbody>
</table>

**Unit Speed at Time of Event**

- Unit Speed: 0%
- Stopping Status: 1
- Braking Status: 1

**12-Month Trends of Rolling Averages**

- Stop Initiate Duration
- Ramp Down Duration
- Braking Duration
- Total Stop Duration
- Tailwater Level: 3.7715 m
- Net Head: No Data

**Graphs**

- Graph showing trend lines for various durations and statuses.
- Graphs indicating rolling averages for different events.

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**Meridian.AVEVA**
Use Cases

Hydro Unit Stopping Sequence Analysis

Hydro Unit Fatigue Monitoring
Hydro Unit Fatigue Monitoring

Problem

• Meridian Energy has no indication of unit fatigue correlating to raw, real-time data

• Lack of visibility into hydro operating metrics

• Insufficient data to drive condition-based maintenance decisions
Hydro Unit Fatigue Monitoring

Approach

• Use time-series data from AVEVA’s PI system with PI Asset Framework and PI Vision

• Perform expression analysis to gain insights into operating metrics such as:
  • Unit starts/stops
  • Tailwater Depression (TWD) operations
  • Station loading
  • Time within various generation ranges
## Unit Fatigue Monitoring

### General

<table>
<thead>
<tr>
<th>Category</th>
<th>Name</th>
<th>Description</th>
<th>Default Value</th>
<th>Settings...</th>
</tr>
</thead>
<tbody>
<tr>
<td>Category: Configuration</td>
<td>Configurable Values</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Overload Threshold</td>
<td>0 MW</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rough Running Threshold High</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rough Running Threshold Low</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Transition Threshold High</td>
<td>0 MW</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Transition Threshold Low</td>
<td>0 MW</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Flags

- **CB Closed Flag**: OR TRIPPED
- **CB Open Flag**: Unit stops within 10 minutes of...
- **Short Started Time Flag**: Unit starts within 10 minutes of...
- **Short Stopped Time Flag**: Within the transition range

### Input

- **Gen SP MW**: Gen SP MW
- **Start PB**: Start PB
- **Stop PB**: Stop PB
- **TWO Status**: TWO
- **Unit CB Status**: Unit CB

### Output

- **Hours in OL**: Hours in Overload Range
- **Hours in OP**: Hours in Operating Range
- **Hours in RR**: Hours in Rough Running Range
- **Hours in SNL**: Hours in Speed No Load Range
- **Hours in TWD**: Hours in Tailwater Depression
- **Rough Running Count**: Total number of times a unit...
- **Unit Short Start Count**: Cumulative unit stops within 10...
- **Unit Short Stop Count**: Cumulative unit starts within 10...
Example Element:

**Meridian.AVEVA**

### Add a new Variable

<table>
<thead>
<tr>
<th>Name</th>
<th>Expression</th>
<th>Output Attribute</th>
</tr>
</thead>
<tbody>
<tr>
<td>Now</td>
<td>'5'</td>
<td>Map</td>
</tr>
<tr>
<td>UnitRunning</td>
<td>TagVal('Unit Speed', Now) &gt; 95</td>
<td>Map</td>
</tr>
<tr>
<td>RoughRunning</td>
<td>if UnitRunning and 'TW0 Status' &lt;&gt; 1 and TagVal('Gen Set Point MW', Now) &lt;= 'Rough Running Threshold Low' then 1 else 0</td>
<td>Map</td>
</tr>
</tbody>
</table>

#### OperationState

// Check which state running range is, and assign value based on UnitRunRangeState ENUM

```java
if UnitRunning then
    if TagVal('TW0 Status', Now) = 1 then "TW0"
    else if SpeedNoLoad then "SpeedNoLoad"
    else if RoughRunning then "RoughRunning"
    else if Operating then "Operating"
    else if Overload then "Overload"
    else -99
else "NotRunning"
```

### OperationStateOut

```java
//if UnitRunning then
    //if TagVal('TW0 Status', Now) = 1 then 1
    //else if SpeedNoLoad then 2
    //else if RoughRunning then 3
    //else if Operating then 4
    //else if Overload then 5
    //else -99
else 0
if BadVal(TagVal('RunRangeState', Now)) or TagVal('RunRangeState', Now) <> OperationState then OperationState else NoOutput()
```
Future Work Examples

- Overload Analysis
  - Revenue
  - Maintenance frequency
- Operational Vibration Analysis
  - Monitoring and Alarming
- Component condition heat map
  - Simple colour-coded condition visual
  - Single metric to describe unit fatigue
  - Similar degradation rates
Results and Benefits

Hydro unit stopping sequence analysis
• Provided data points and visuals of all prior stopping sequences to provide insights into component-level conditions
• Created trends of unit stopping times to monitor degradation of generating asset components over time

Hydro unit fatigue monitoring
• Highlights the way we operate our generating assets
• Provides foundation for future, complex analytics
Results and Benefits

AVEVA’s PI System
• Provided foundation to build up a hierarchy of virtual assets increasing accessibility to critical plant information

PI Asset Framework
• Contextualise and format data for various business units
• Monitor events using start and end triggers whilst capturing relevant data
• Notify the right people at the right time when the plants are performing unexpectedly

PI Vision
• Integrate analytical data into graphs and displays to show only what is required
Meridian Energy has reduced the need for plant outages to perform analytics by increasing asset transparency with AVEVA’s PI System

Challenge
• Lack of visibility into our generating assets
• Requiring plant outages and routine maintenance to investigate the degradation of our generating assets
• Outage flexibility becoming less frequent due to constraints from market demand

Solution
• Integration of AVEVA’s PI System, PI Asset Framework, and PI Vision to collect, analyse, and contextualise critical metrics within our generating assets

Results
• Created processes to collect and contextualise information and deliver it to various business units in relevant formats
• Developed a centralised platform to present data at different depths to accommodate all levels of interest
Looking Ahead

Building more foundational models and expanding on these with more complex analytics

Integrate bi-directional channel between PI System and work management system

Manage alarms and notifications through Asset Framework

Integrate PI Web API into our pipeline
Questions?
Please wait for the microphone.
State your name and company.

Please remember to...
Navigate to this session in the mobile app to complete the survey.
William Herewini

Engineering Data Analyst

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Saif Fawzi

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Over 20,000 enterprises in over 100 countries rely on AVEVA to help them deliver life’s essentials: safe and reliable energy, food, medicines, infrastructure and more. By connecting people with trusted information and AI-enriched insights, AVEVA enables teams to engineer efficiently and optimize operations, driving growth and sustainability.

Named as one of the world’s most innovative companies, AVEVA supports customers with open solutions and the expertise of more than 6,400 employees, 5,000 partners and 5,700 certified developers. The company is headquartered in Cambridge, UK.

Learn more at www.aveva.com