19 MAY 2022

Get Integrated: Connect AI to Your AVEVA PI System

Francesco PETRONE, Senior Technical Solutions Engineer, AVEVA Predictive Analytics

Giulio CATTARIN, Pre-Sales Engineer, AVEVA

Connect the power of information and AI with human insight

Two world class industrial software experts combine to deliver integrated value

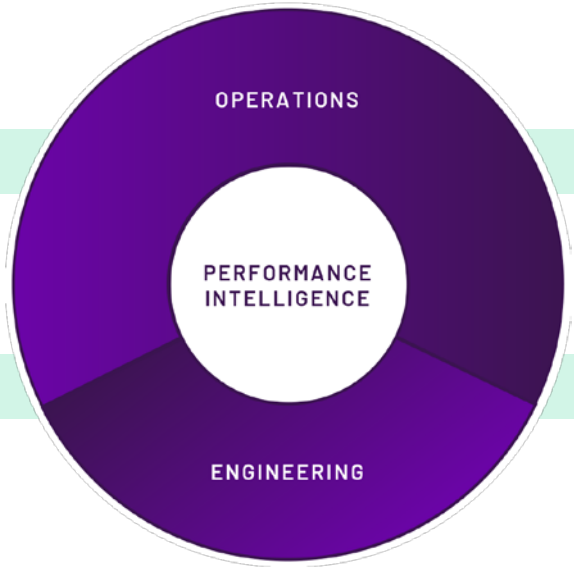
AVEVA's end-to-end industrial software to optimize engineering and operations

+

OSIsoft's PI System is the industry standard for industrial information management

1. Run **agile, continuously optimized** operations to protect the bottom line
2. Increase **asset reliability and safety** with reduced manual supervision
3. Provide remote teams rich data and **decision support** to **collaborate** and work efficiently
4. Maximize CapEx and drive the highest levels of **engineering efficiency**

AVEVA



OSIsoft. is now part of AVEVA


Automation/ Control Systems


New Sensor Tech


Remote + Mobile Assets

AVEVA

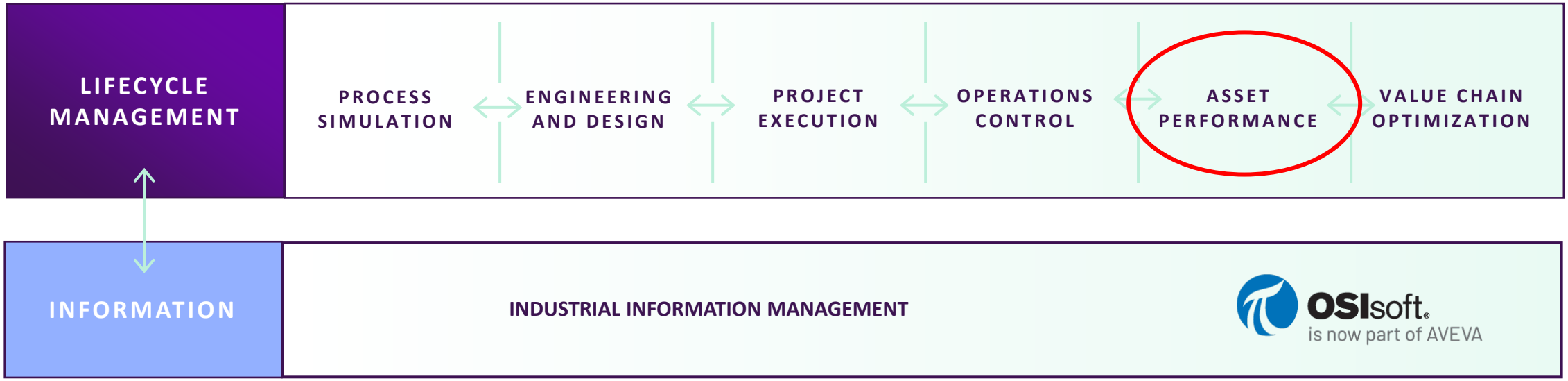
Combining world-class software to drive Performance Intelligence

Accelerating digital transformation of the industrial world with complementary product offerings

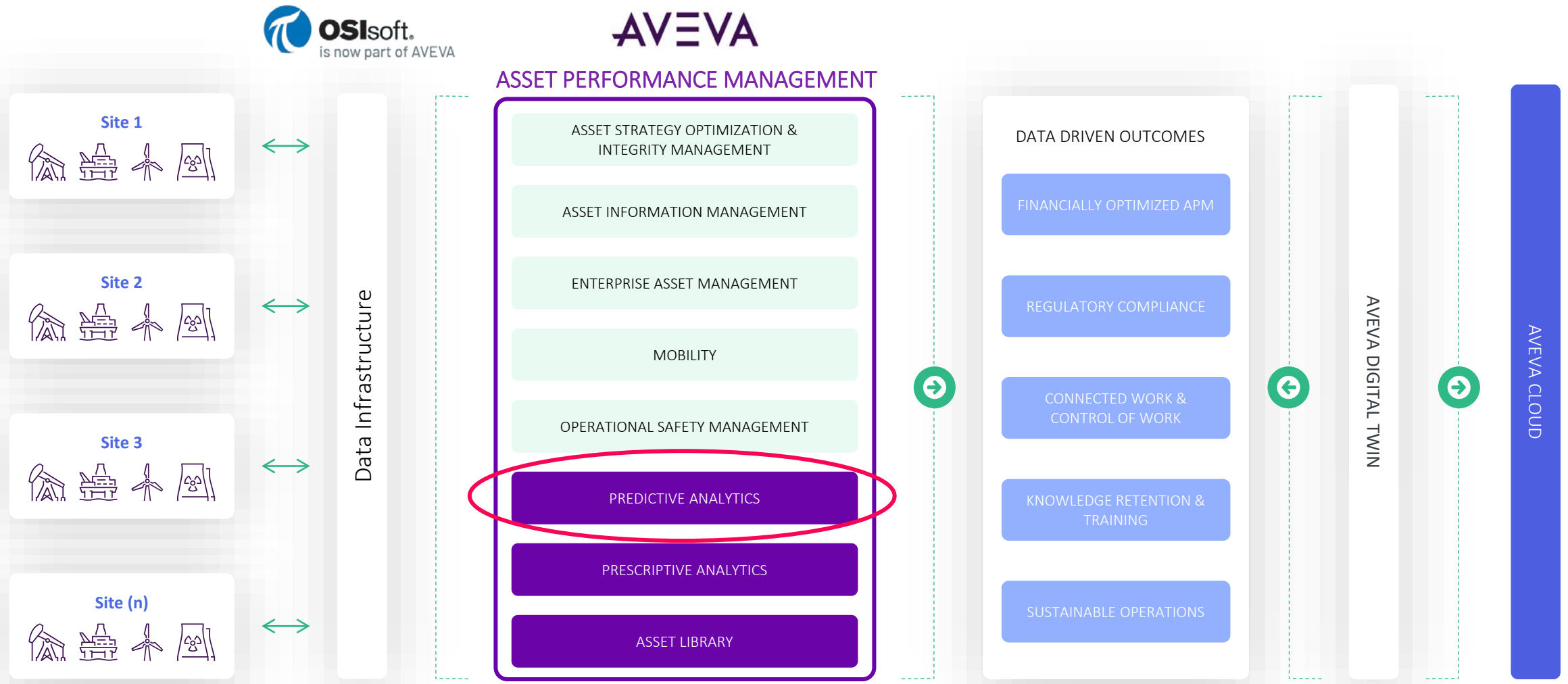
AVEVA's end-to-end industrial software to optimize engineering and operations

+

OSIsoft's PI System is the industry standard for industrial information management



AVEVA PI System + AVEVA APM – the Complete Picture



AVEVA

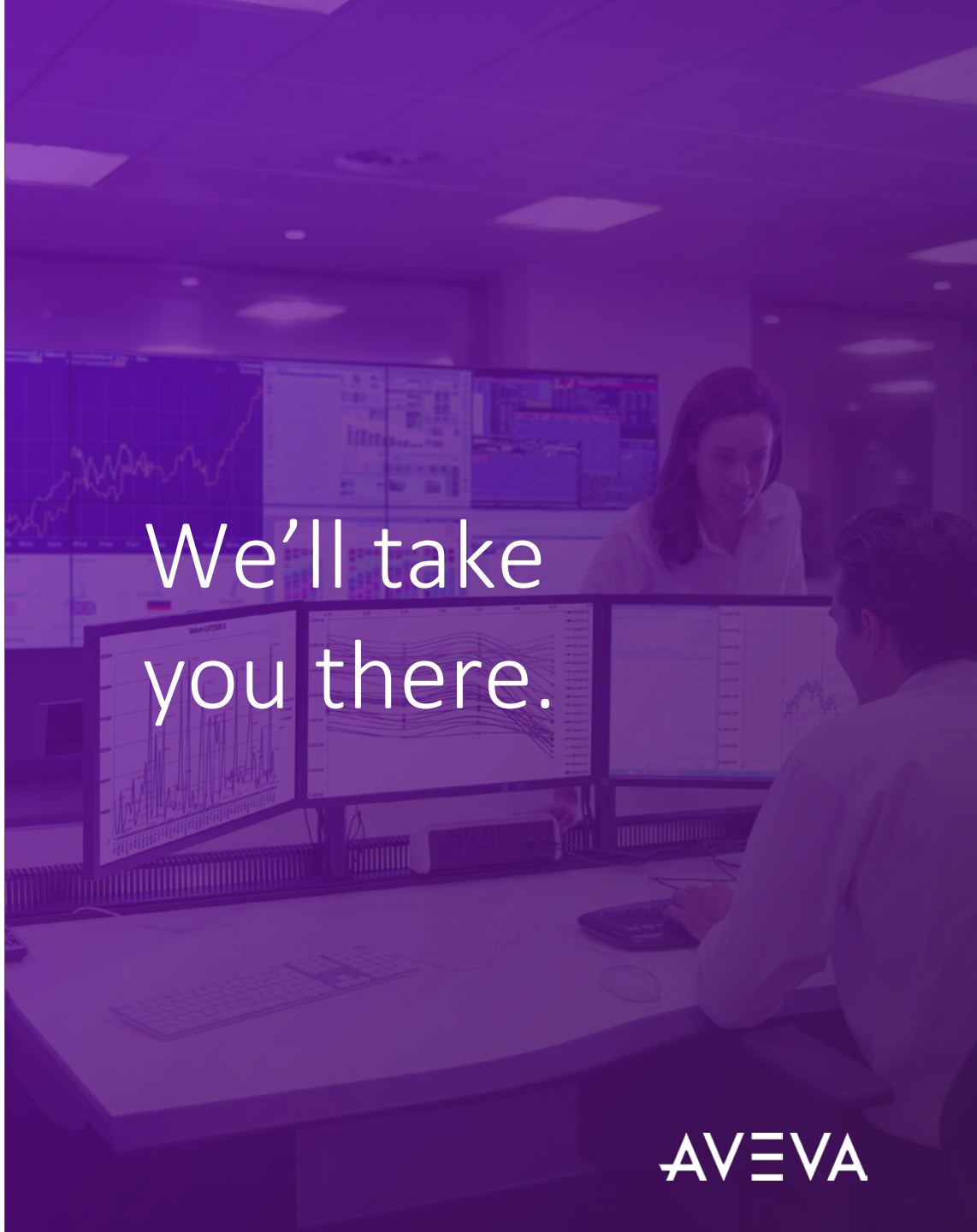
AVEVA Predictive Analytics

Profits are hit by unscheduled downtime, inconsistent work execution, over and under maintenance.

What if you could get **early notification** of asset issues before they lead to unscheduled downtime?

What if you could **reduce operational expenditure** by improving efficiency and reliability?

AVEVA Predictive Analytics takes the rich data available in your PI System and turns it into **actionable insights** to prevent equipment failures.



Agenda

- AVEVA Predictive Analytics
  - General concepts
  - Model building
  - Monitoring - Alert & Case Management, Fault Diagnostics and Forecast
  - Getting started and scaling up
- AVEVA Predictive Analytics and AVEVA PI System: a match made in heaven!
  - Current integration and architecture roadmap
  - Demo - Wind farm performance and health monitoring
  - Leveraging Asset Framework in AVEVA Predictive Analytics
- Key takeaways
- Q&A

AVEVA Predictive Analytics

General concepts

AVEVA Predictive Analytics

Anomaly detection for business-critical equipment.

Historical Data

- Data collection from AVEVA PI System

Pattern Recognition

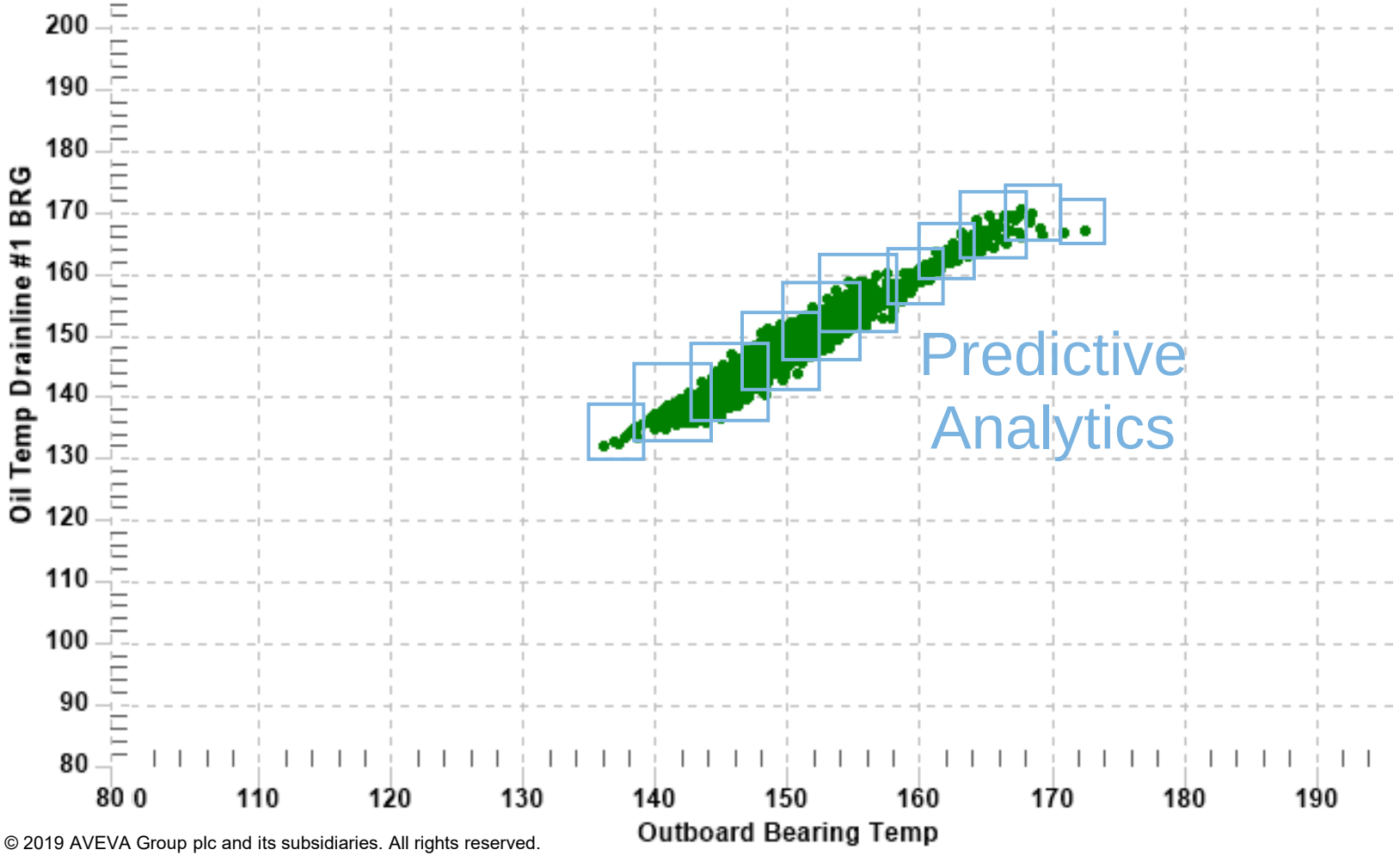
- Data-driven equipment model
- AI continuous monitoring

Early Warning

- Alert / Case management
- Analysis tools

AVEVA Predictive Analytics - General concepts

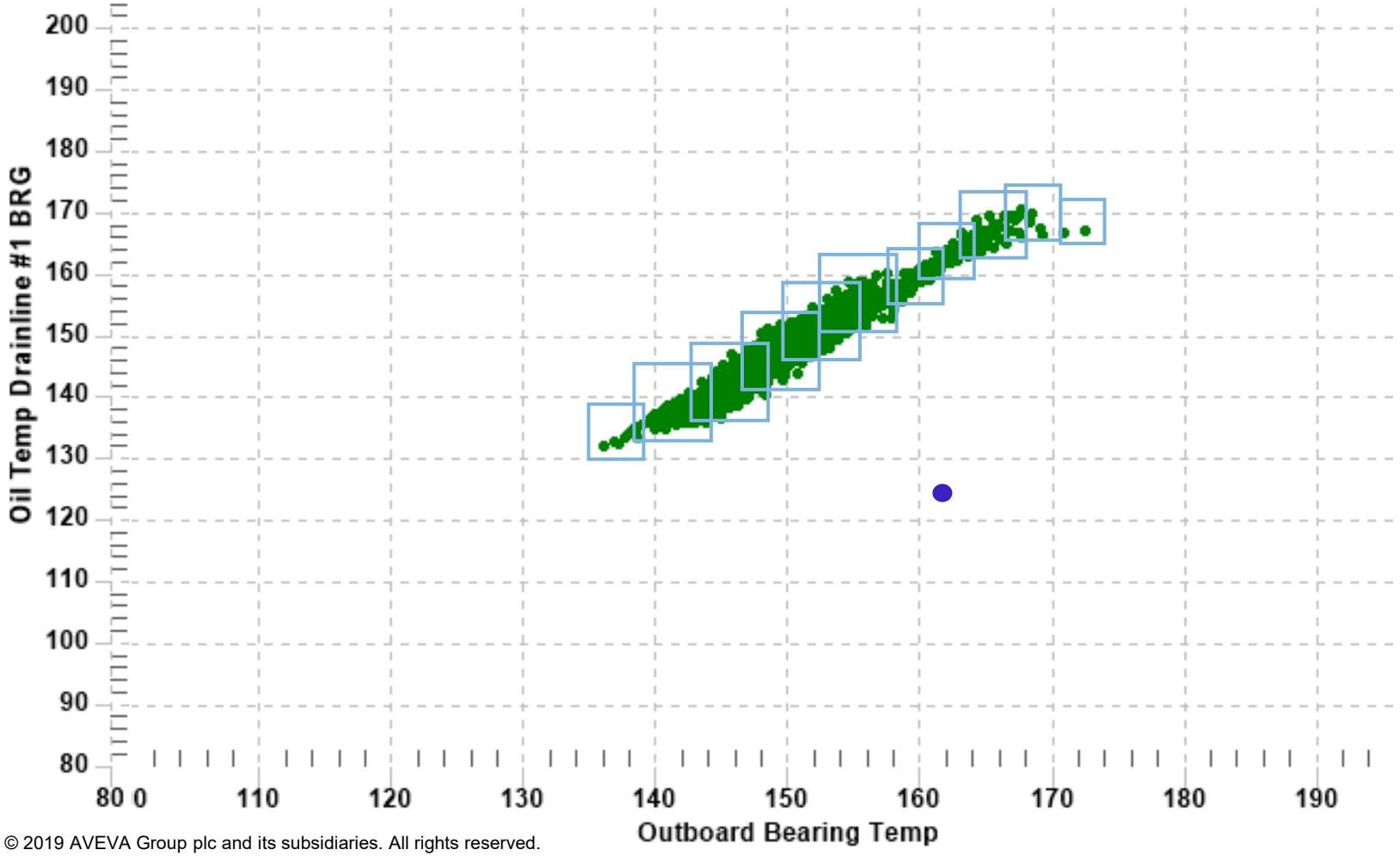
Data clustering



- Historical data encoded with data clustering algorithms
- Clusters describe known relationships in data across N sensor dimension

AVEVA Predictive Analytics - General concepts

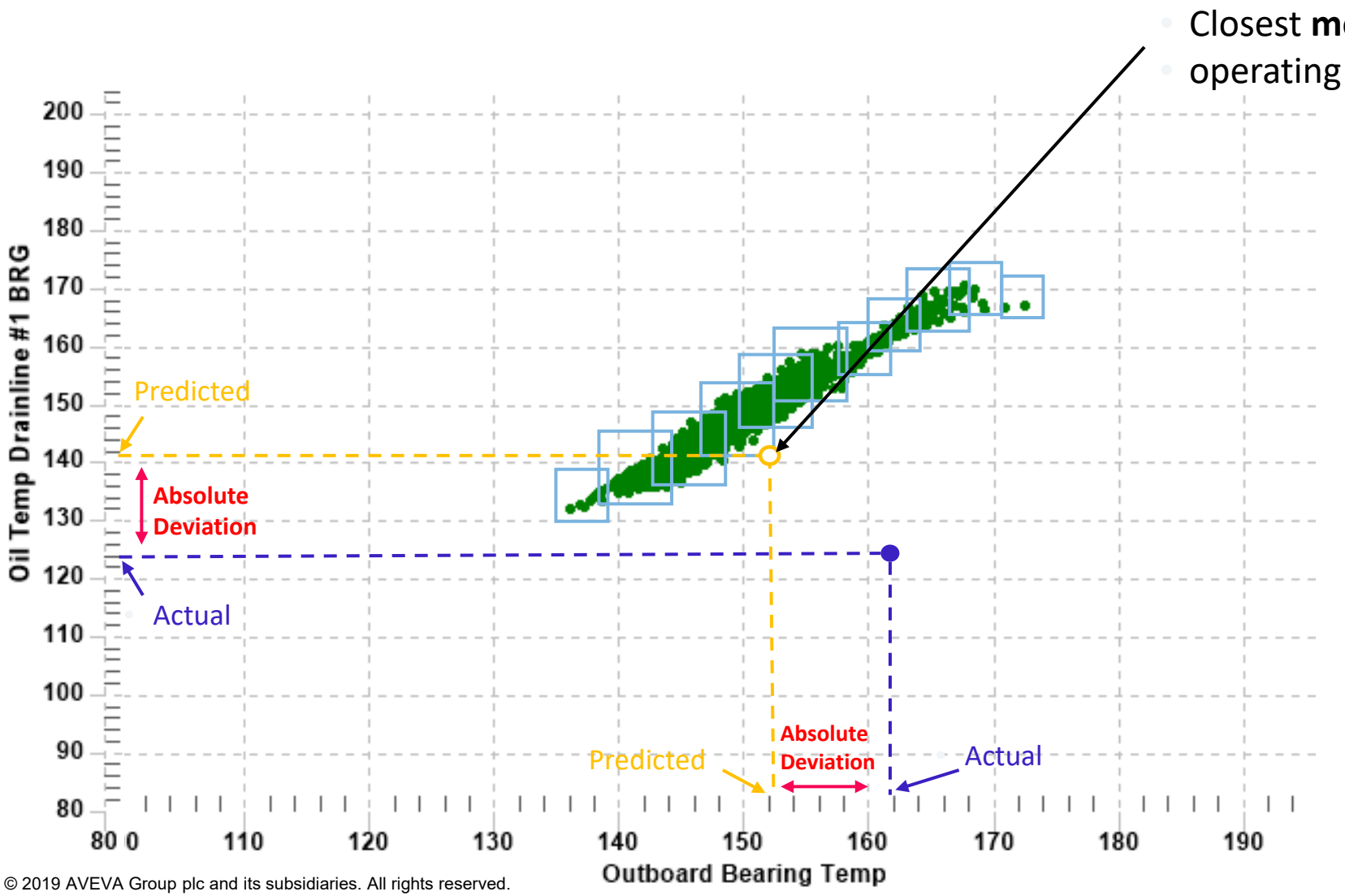
Data clustering



- New data is compared against clusters to detect deviations in behavior in real-time
- Algorithm computes magnitude of deviations and which sensor(s) are contributors

AVEVA Predictive Analytics - General concepts

Data clustering



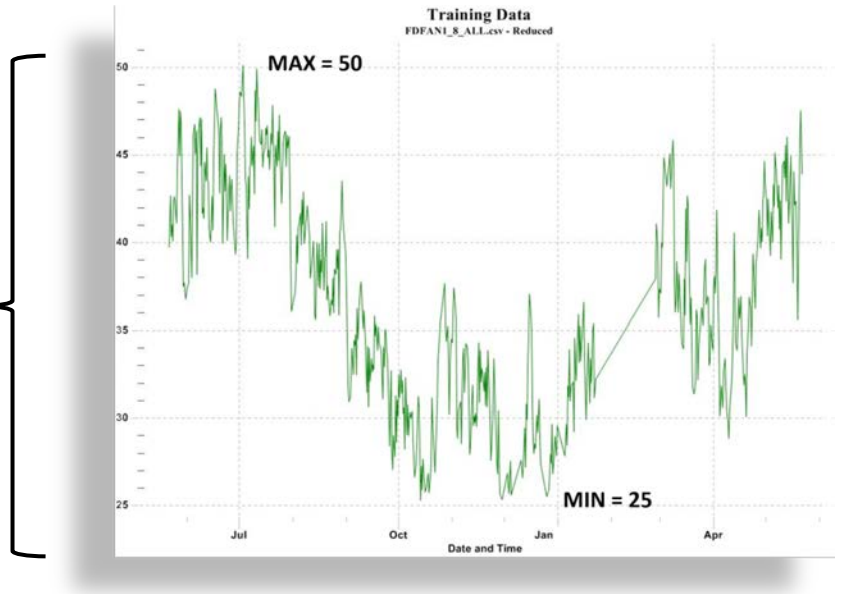
- Real time outputs:
  - Actual Values
  - Predicted Values
  - Absolute Deviations

AVEVA Predictive Analytics - General concepts

Relative Deviation and OMR

Model **Outputs:**

- For **each** variable:
  - **Actual** value
  - **Predicted** value
  - **Absolute** Deviation
  - **Relative** Deviation $= \frac{\text{Absolute Deviation}}{\text{Training Range}} = \Delta X$



- Global indicator:
  - **Overall Model Residual (OMR)** = Root Mean Square of Relative Deviations

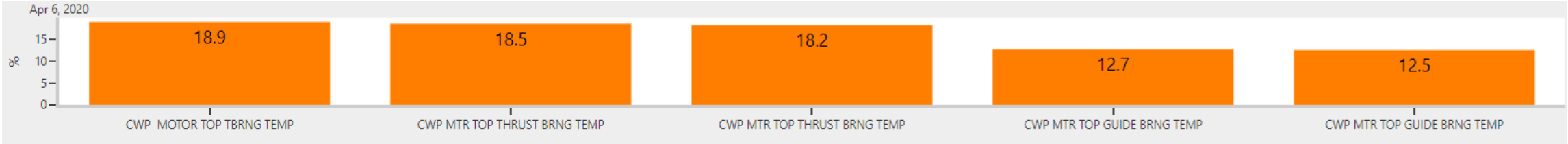
$$OMR = \sqrt{\frac{\Delta X_1^2 + \Delta X_2^2 + \Delta X_3^2 \ \ldots + \Delta X_n^2}{n}} \quad (measured\ in\ \%)$$

Model's distance from expected performance

AVEVA Predictive Analytics - General concepts

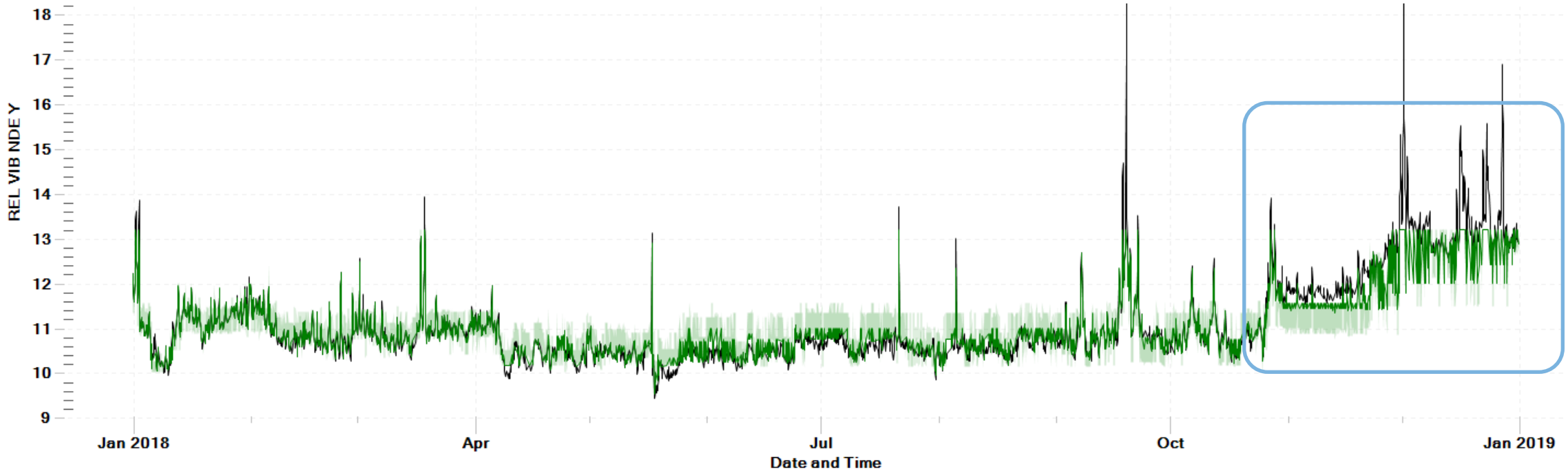
Overall Model Residual

- Overall Model Residual as Asset Health indicator
- Signal Contributions with likelyhood
- Quick troubleshooting capability



AVEVA Predictive Analytics - General concepts

Actual VS Predicted value

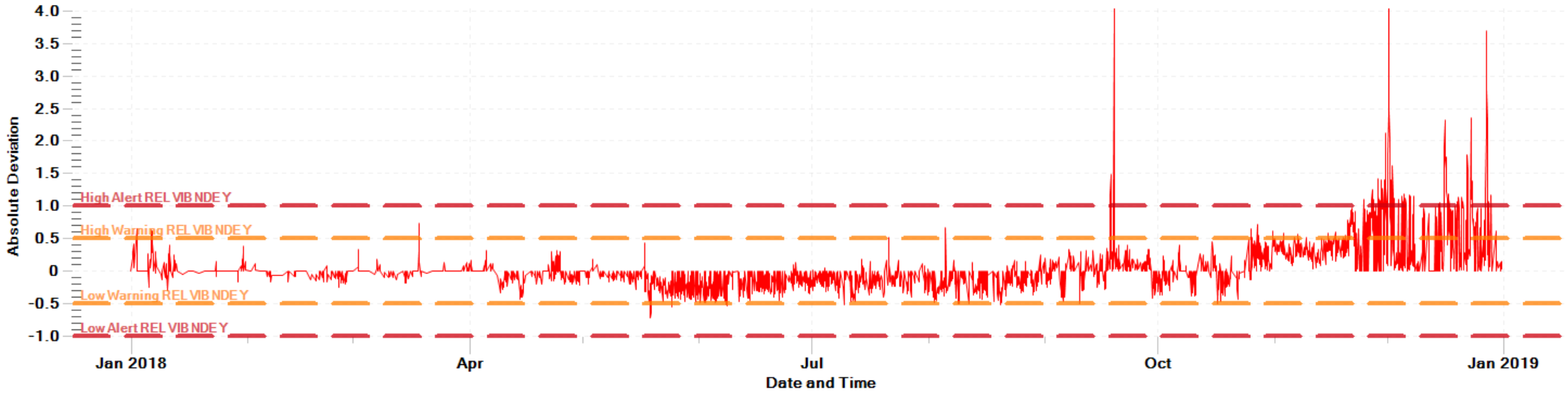


ACTUAL VALUE

PREDICTED VALUE

AVEVA Predictive Analytics - General concepts

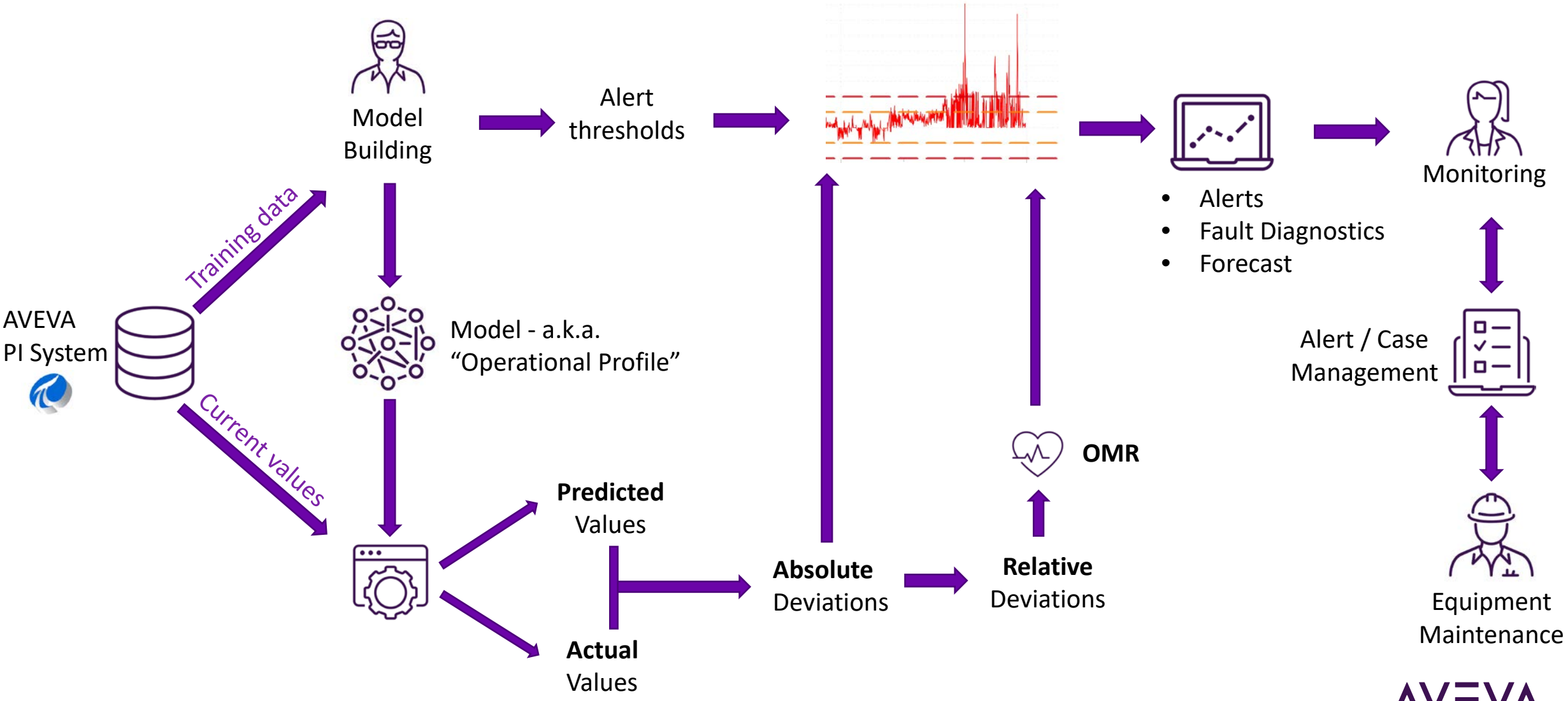
Absolute Deviation



ABSOLUTE DEVIATION

AVEVA Predictive Analytics - General concepts

Workflow

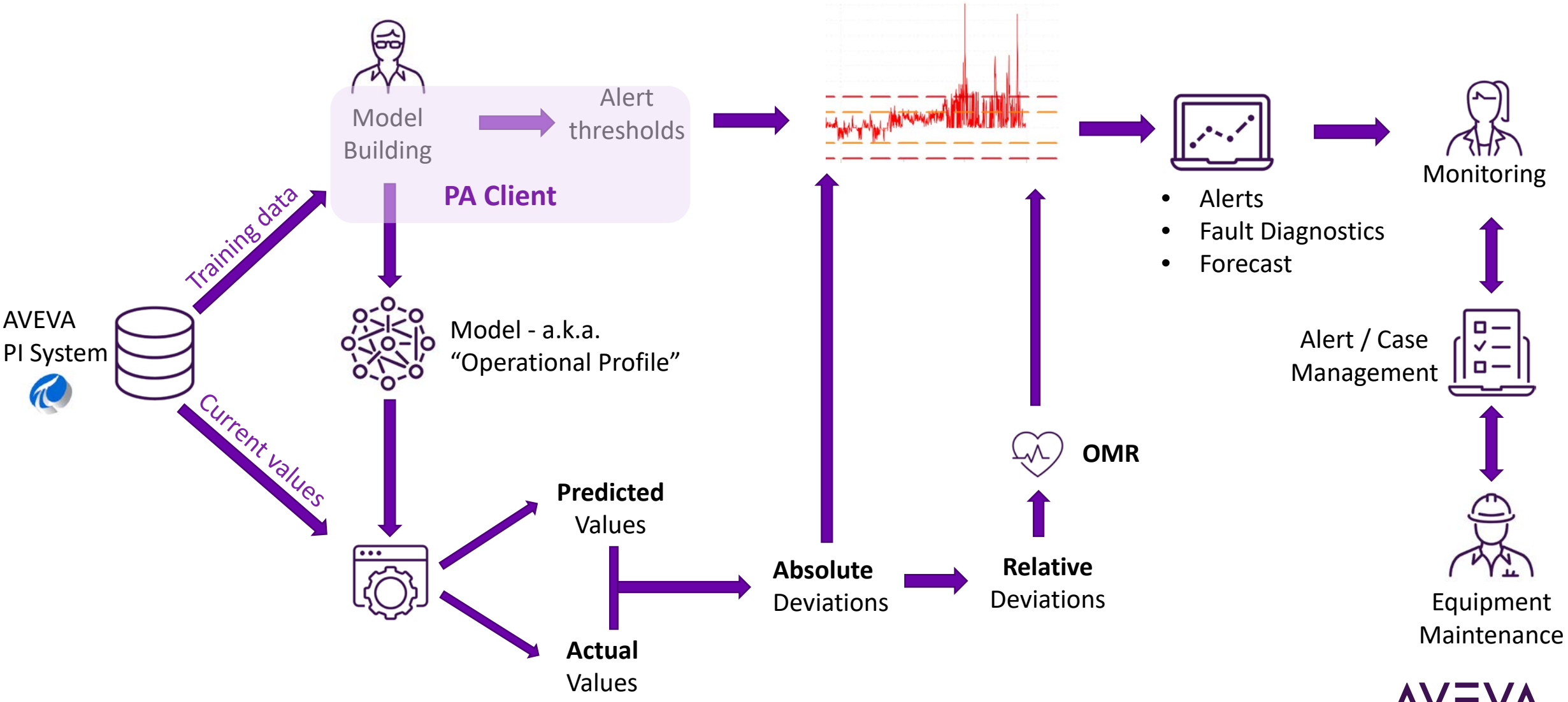


AVEVA Predictive Analytics

Model Building

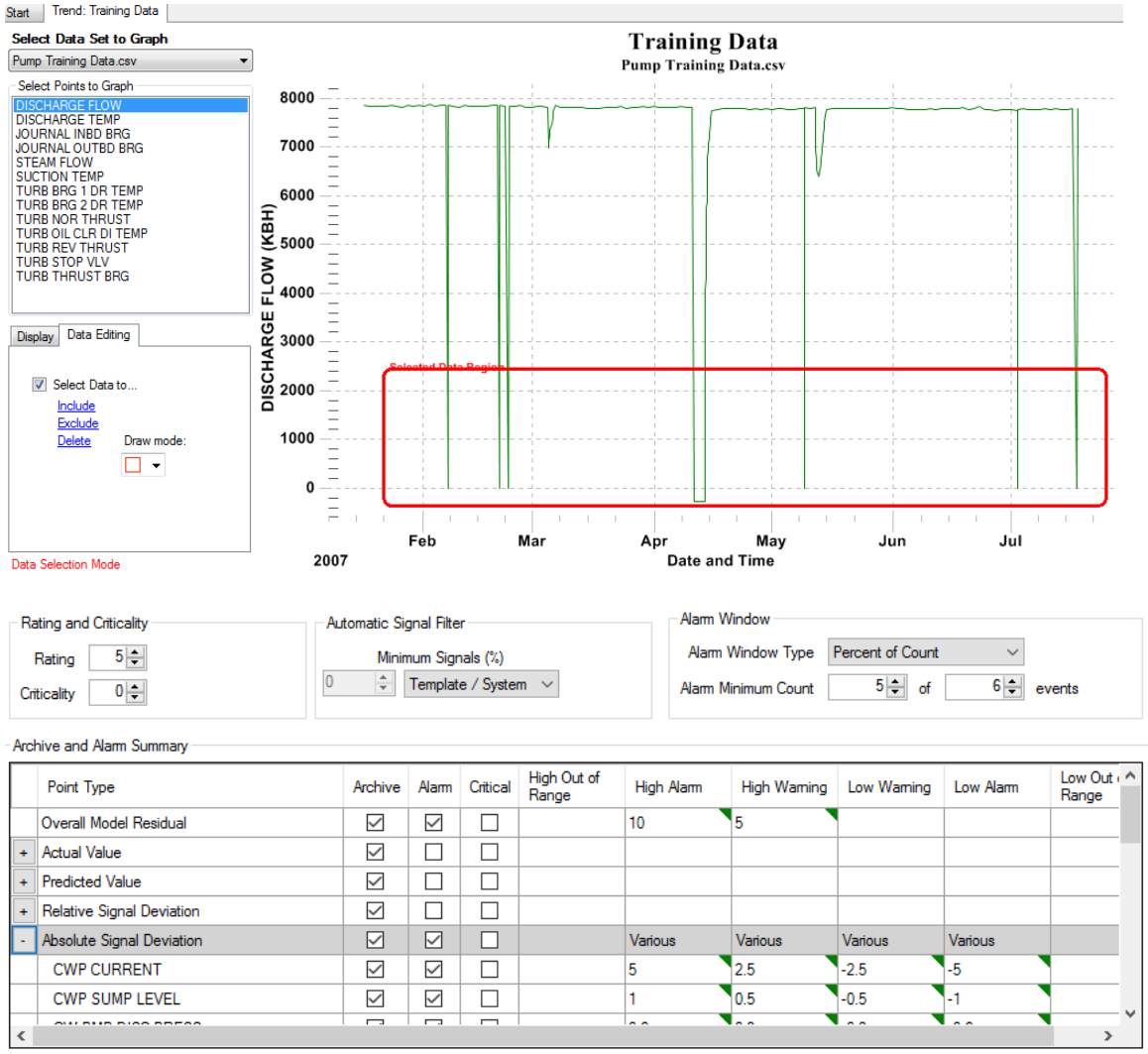
Predictive Analytics – Model Building

Workflow



Predictive Analytics – Model Building

Data cleansing, model training & tuning



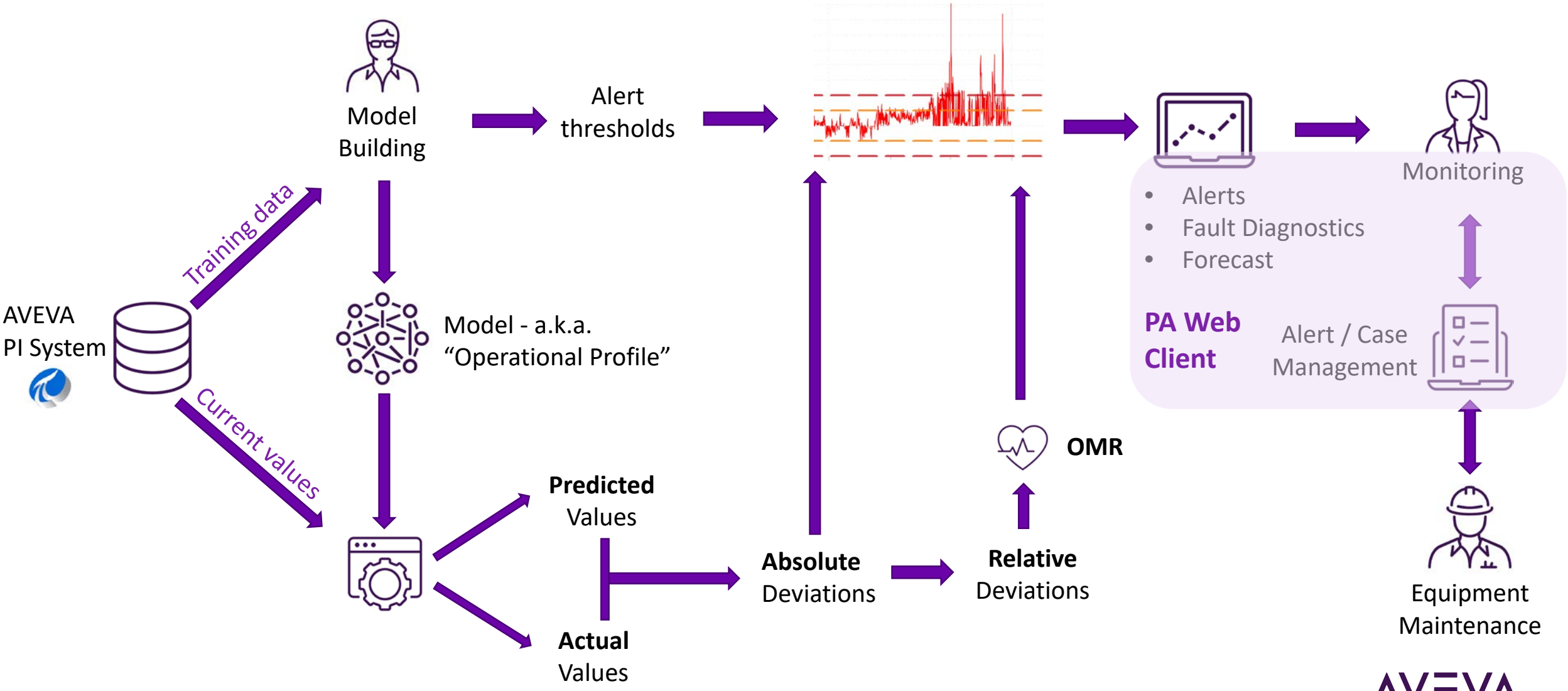
- ✓ User-Friendly Interface
- ✓ Designed for SME
- ✓ No programming Language

AVEVA Predictive Analytics

Monitoring

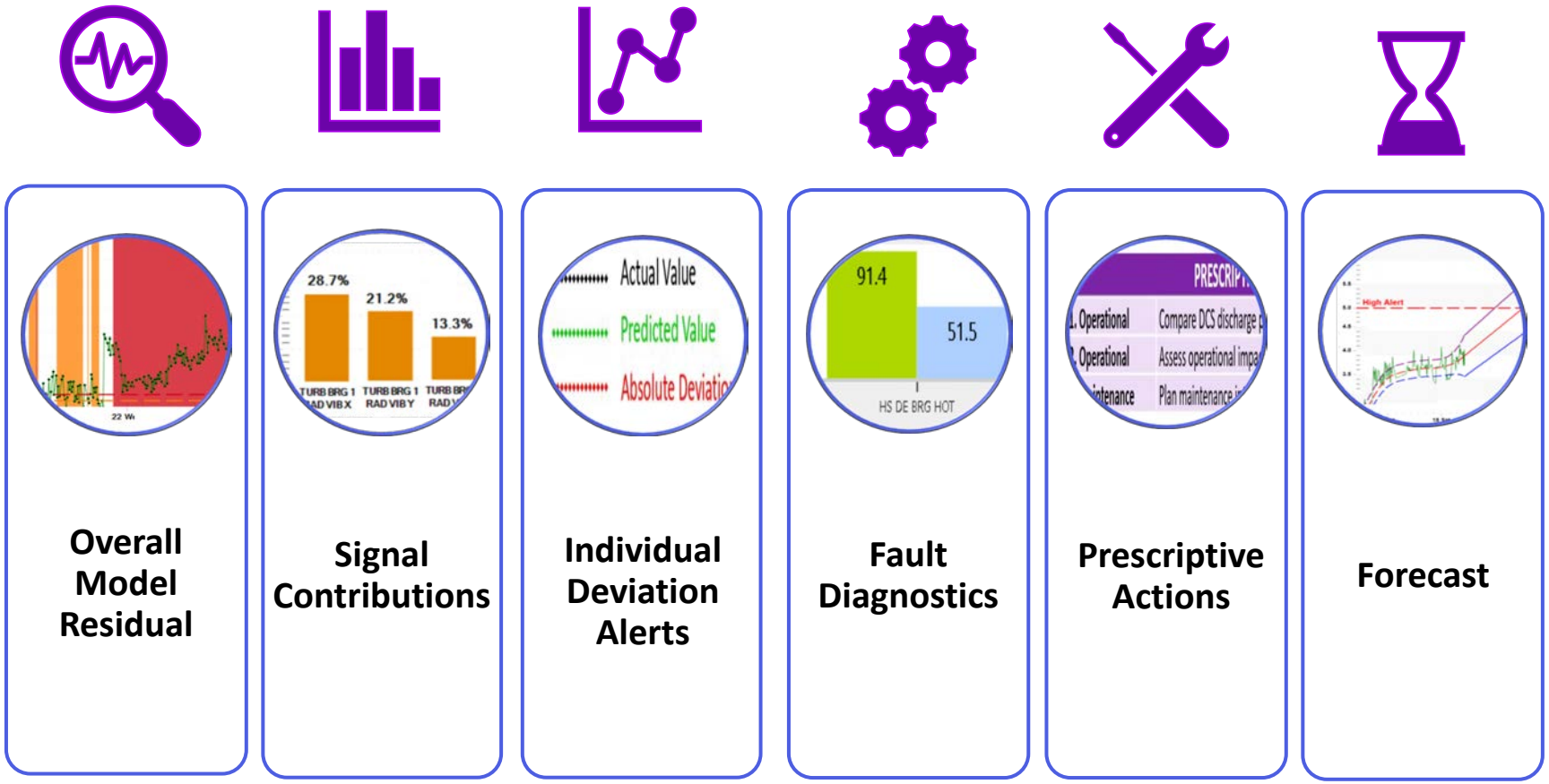
Predictive Analytics – Monitoring

Workflow



Predictive Analytics – Monitoring

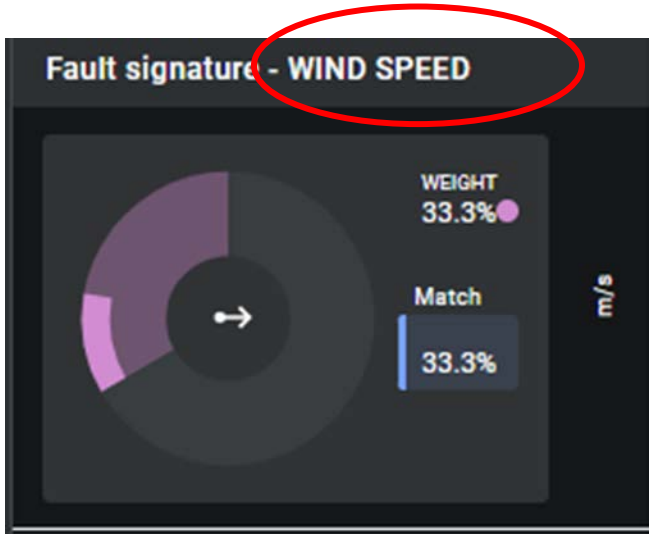
Structured investigation pattern

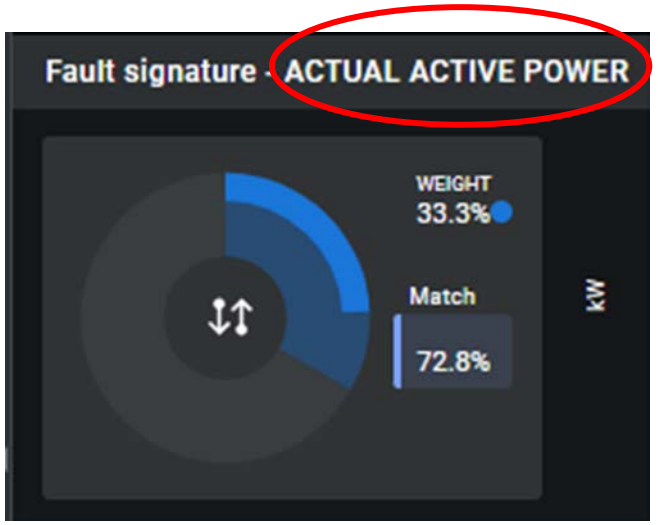


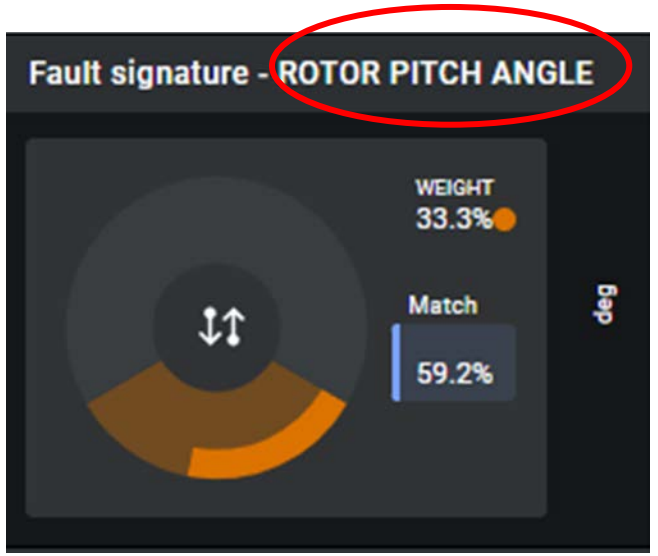
Predictive Analytics – Monitoring

Fault Diagnostics

- **Which** variables are deviating the most?





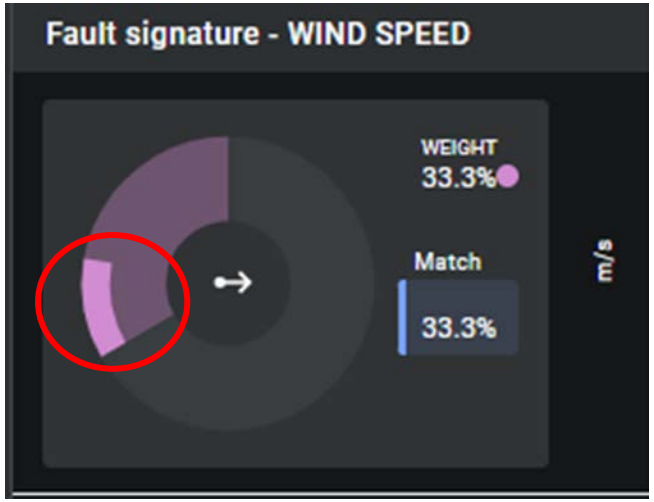


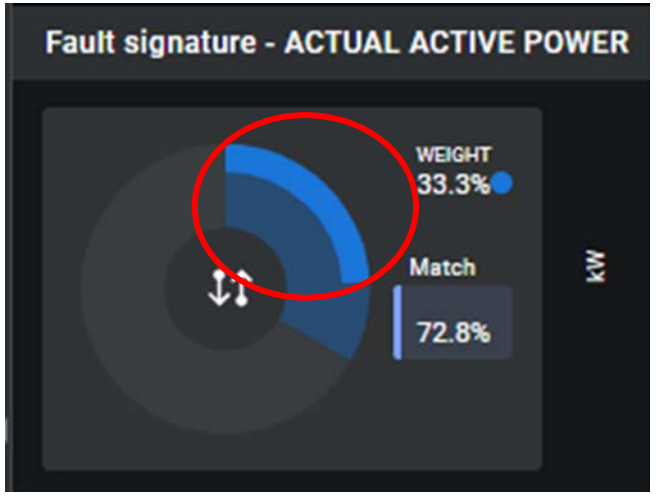
AVEVA

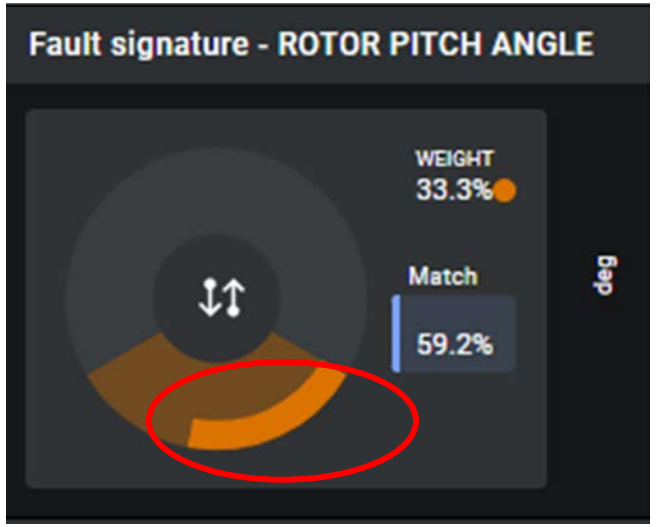
Predictive Analytics – Monitoring

Fault Diagnostics

- **Which** variables are deviating the most?
- **How much** are they deviating?





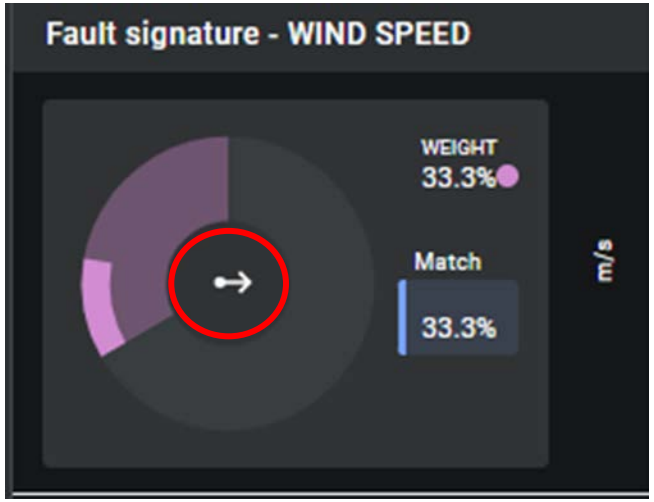


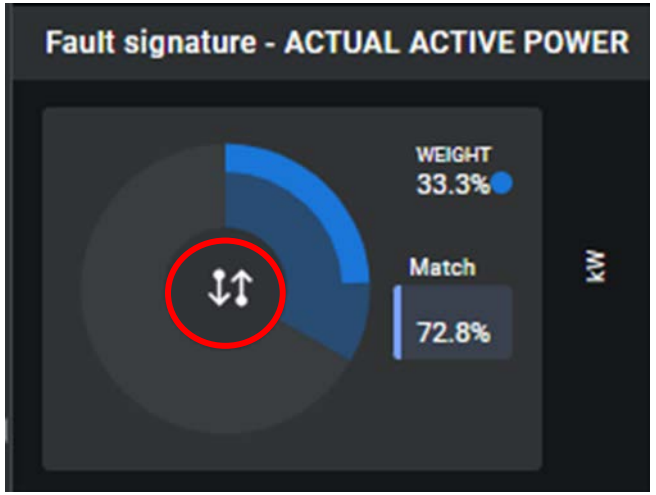
AVEVA

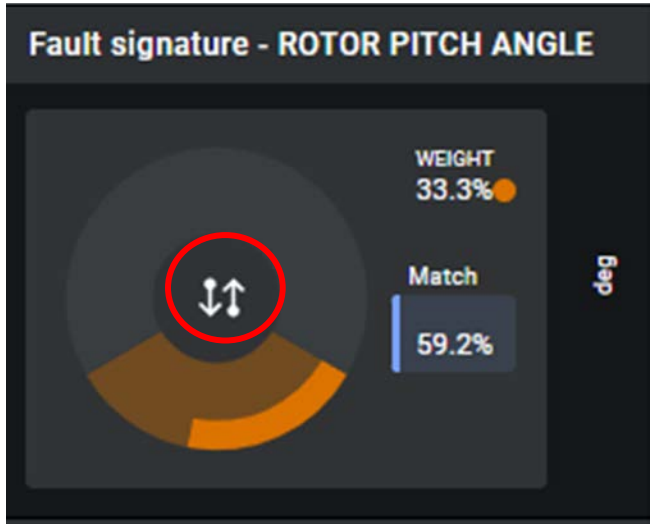
Predictive Analytics – Monitoring

Fault Diagnostics

- **Which** variables are deviating the most?
- **How much** are they deviating?
- In which **direction**?







AVEVA

Predictive Analytics – Monitoring

Fault Diagnostics

- **Which** variables are deviating the most?
- **How much** are they deviating?
- In which **direction**?
- Does this combination match the **signature** of a specific **failure condition**?

ROTOR PITCH FAILURE

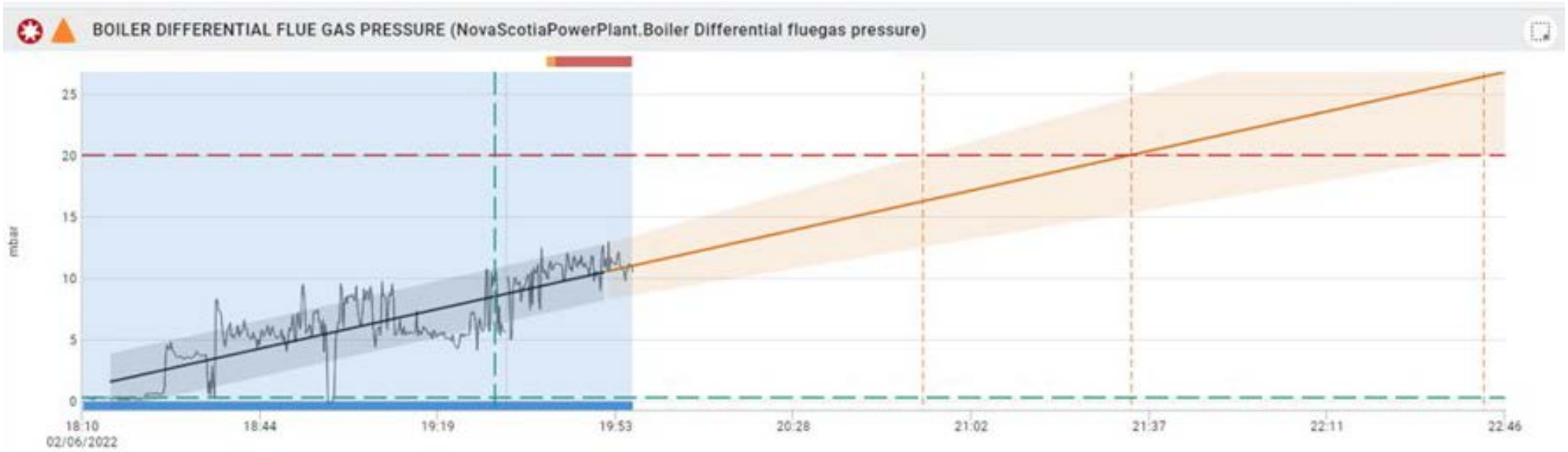
NEXT STEPS

1) Operational - Verify turbine within safe operating limits for wind speed & turbulence. Stop turbine if safety limits exceed.
2) Operational - Verify turbine within overall self protection limits. Stop turbine if safety limits exceed.
3) Operational - Check mechanical model for any concurrent bearing and drive-train issues.

AVEVA

Predictive Analytics – Monitoring

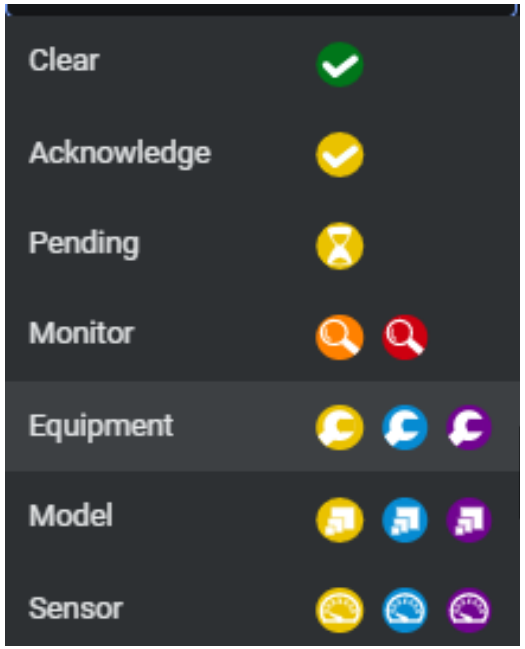
Forecast



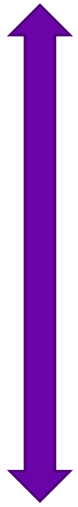
Predictive Analytics – Monitoring

Tracking capability

Alert Management



Monitoring engineer



Maintenance engineer

Case Management

Title	Case Status	Case State	Priority
Active power - low performance		Open	Normal
GE01 Rotor Pitch Failure		Closed	Normal
Pitch angle deviation		Closed	Normal

AVEVA

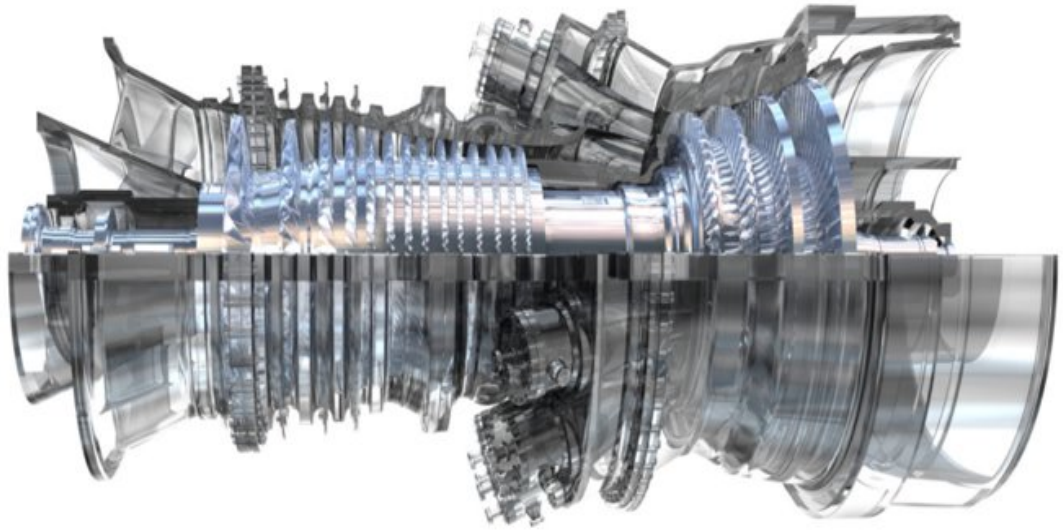
AVEVA Predictive Analytics

Getting started and Scaling up

Predictive Analytics – Getting Started and Scaling Up

Determine Scope

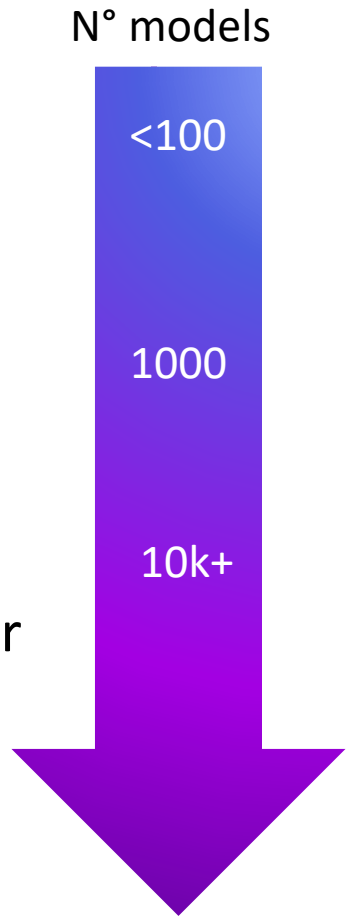
- Wind Turbines
- Hydro Turbines
- Gas Turbines
- Steam Turbines
- Generators
- Boilers
- Pumps
- Motors
- Gearboxes
- Heat Exchangers
- Valves
- Mill’s
- Fans
- Transformers
- Inverters
- Air Heaters



Predictive Analytics – Scaling up

System growth

- Start with **critical** equipment
  - Without redundancy / single point of failure
  - Without spares
  - Costly to repair
  - How often it runs
- Move to secondary equipment later



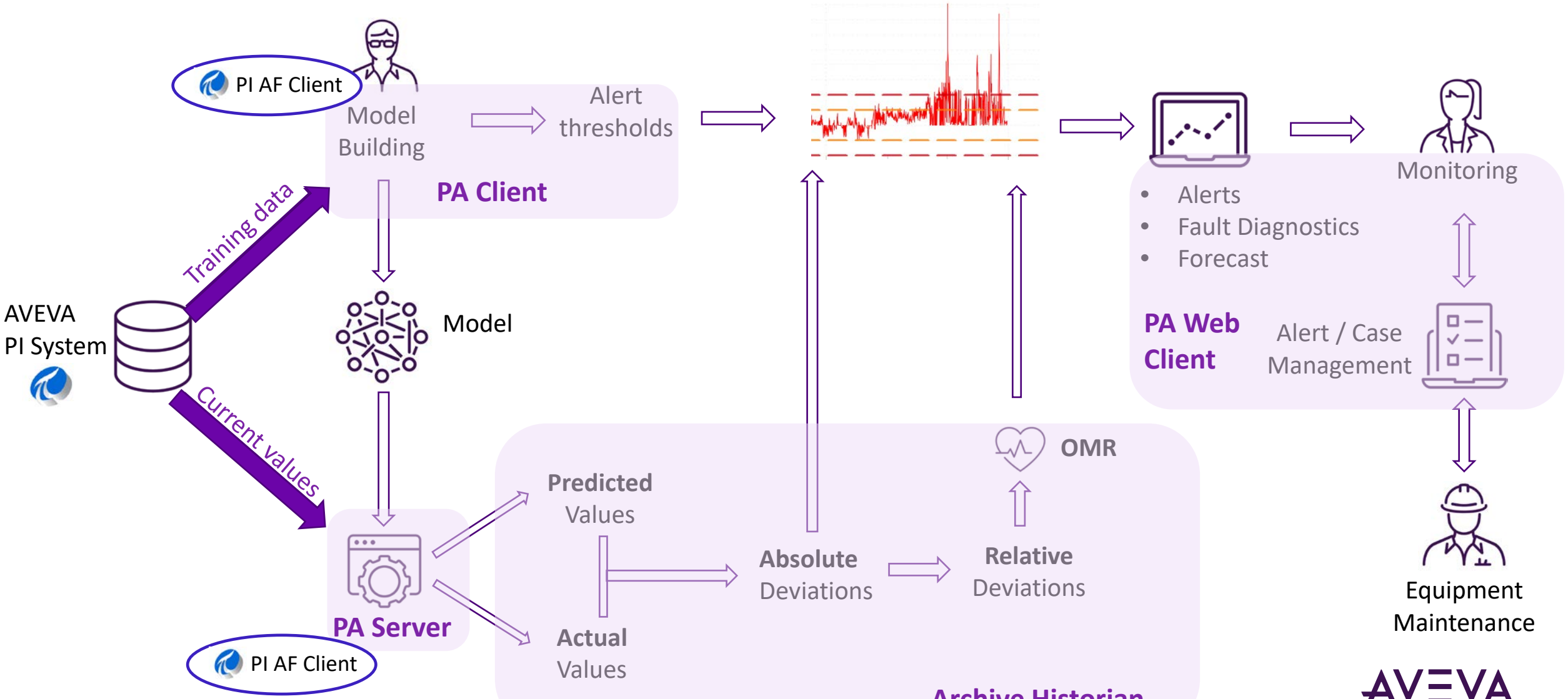
- Instrumentation **availability**
  - Tags exist in the historian
  - Adequate historical data
  - Sufficient resolution / quality of data

AVEVA Predictive Analytics

PI System Integration

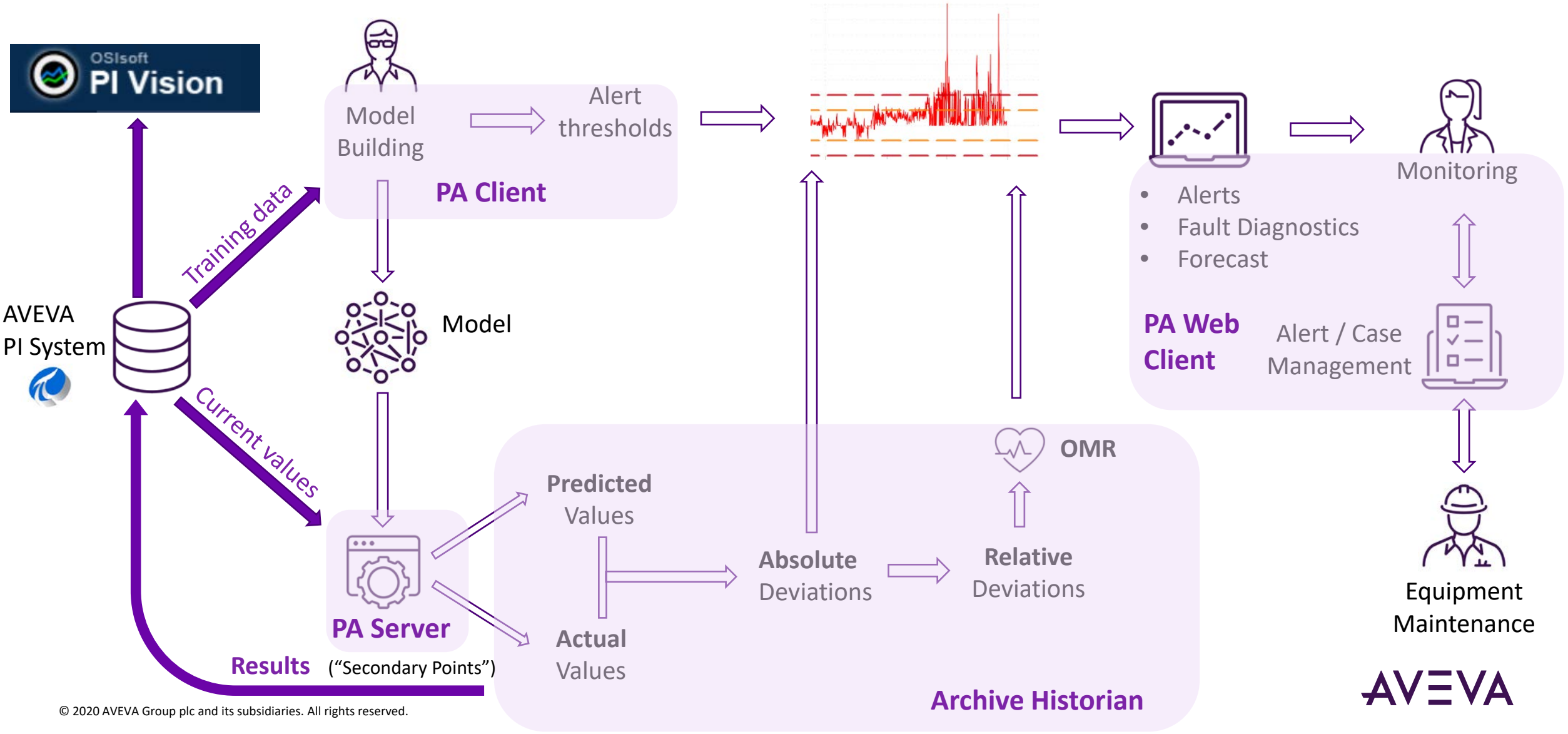
AVEVA Predictive Analytics – PI System Integration

Basic architecture



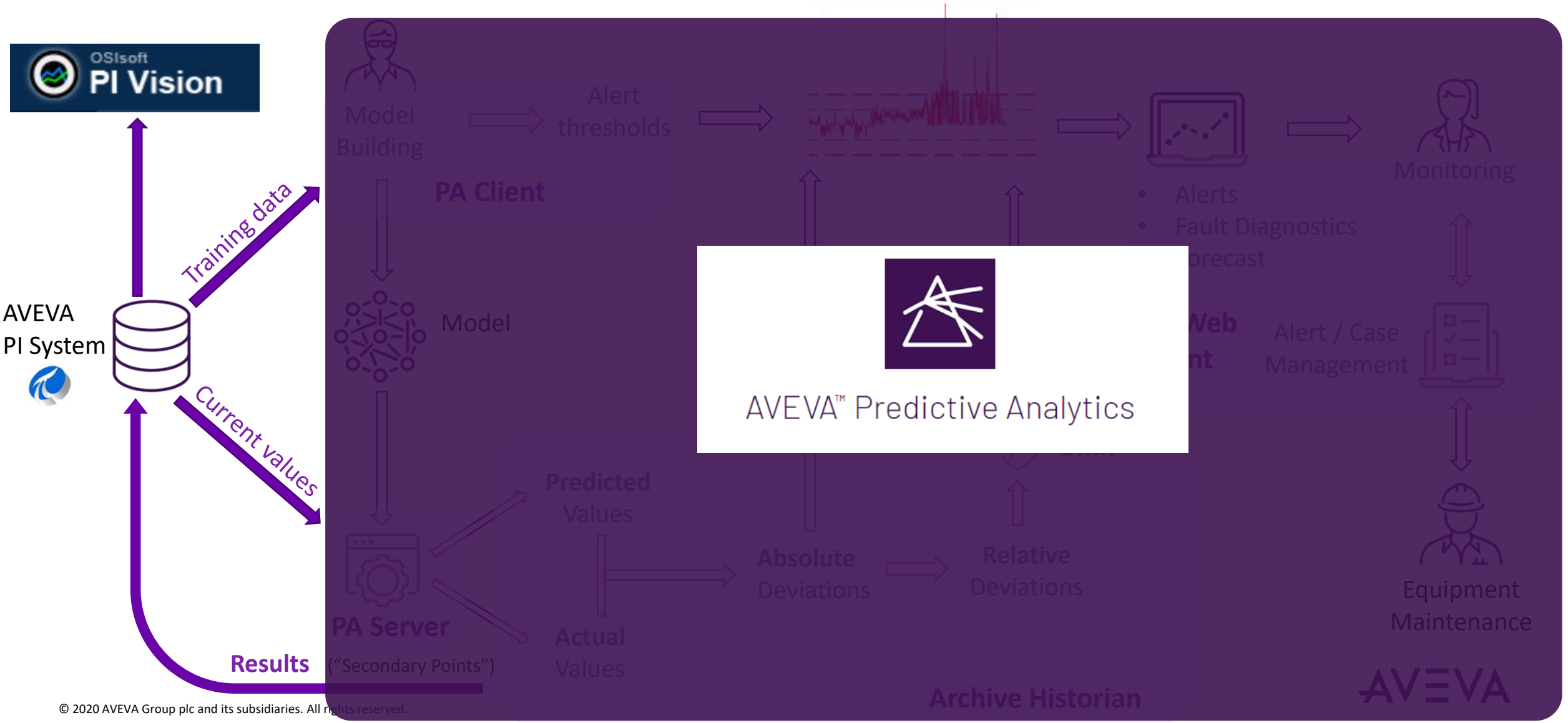
AVEVA Predictive Analytics – PI System Integration

Results feedback



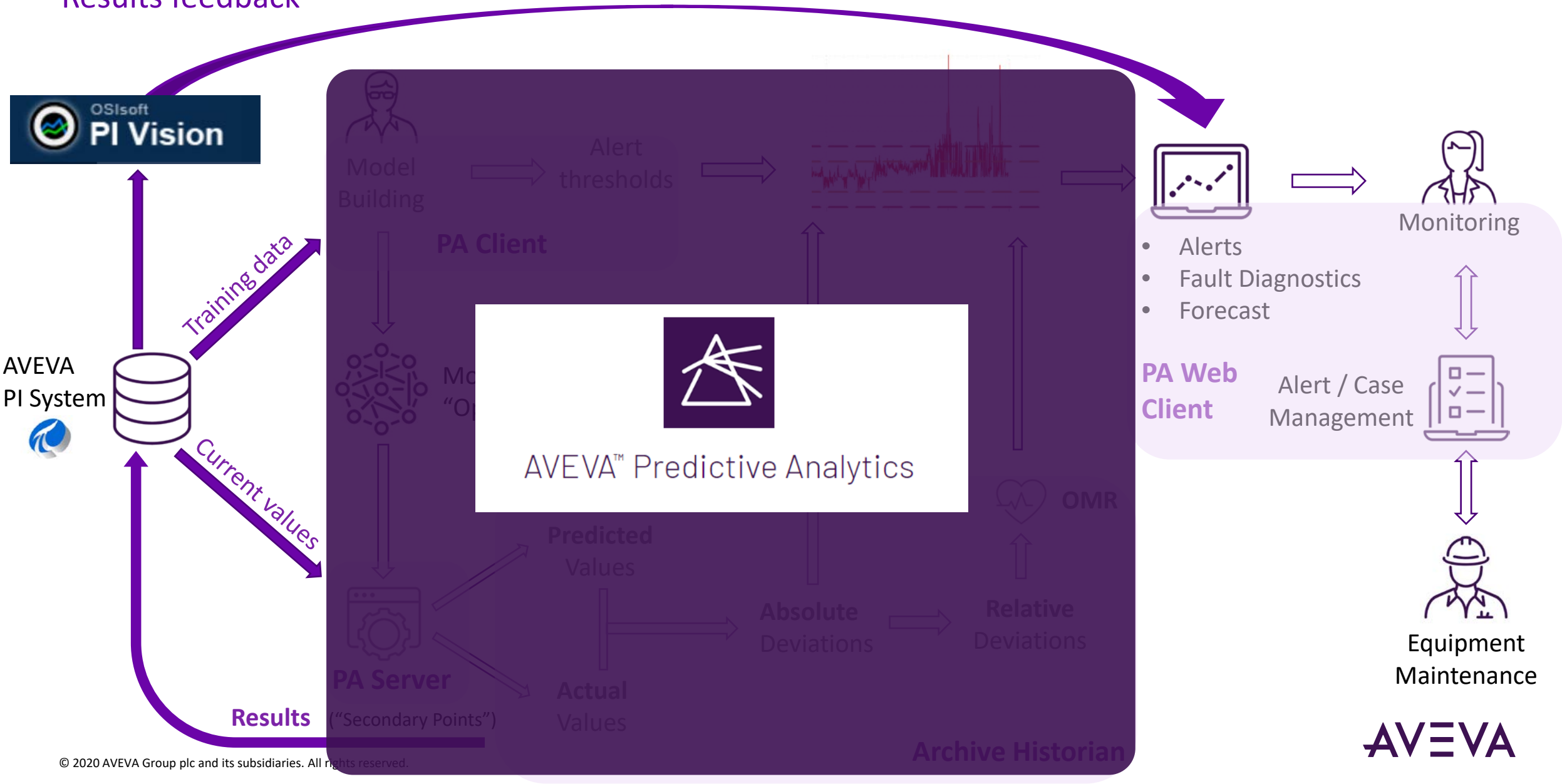
AVEVA Predictive Analytics – PI System Integration

Results feedback



AVEVA Predictive Analytics – PI System Integration

Results feedback

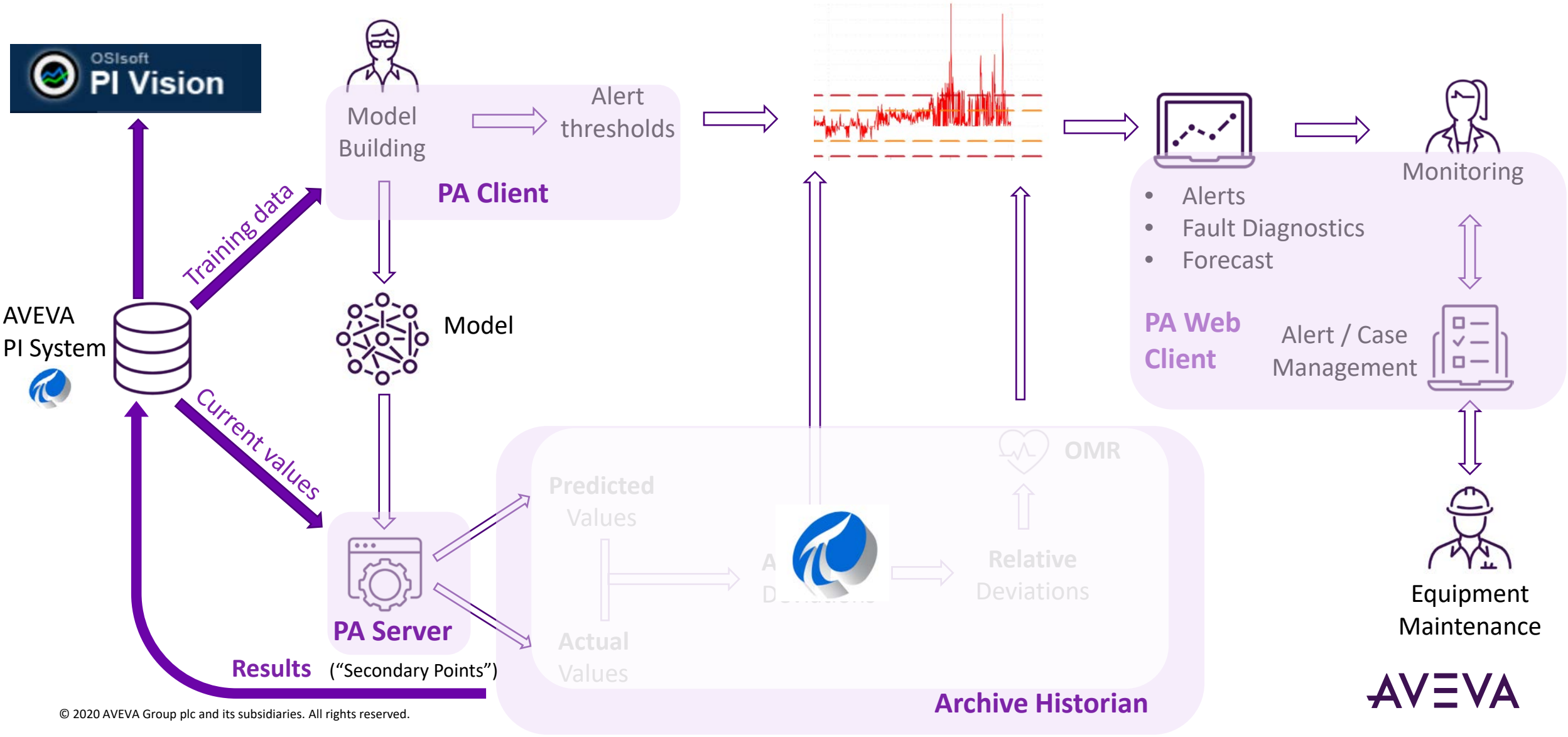


AVEVA Predictive Analytics

Architecture roadmap

Predictive Analytics – Architecture roadmap

PI System as native Archive Historian

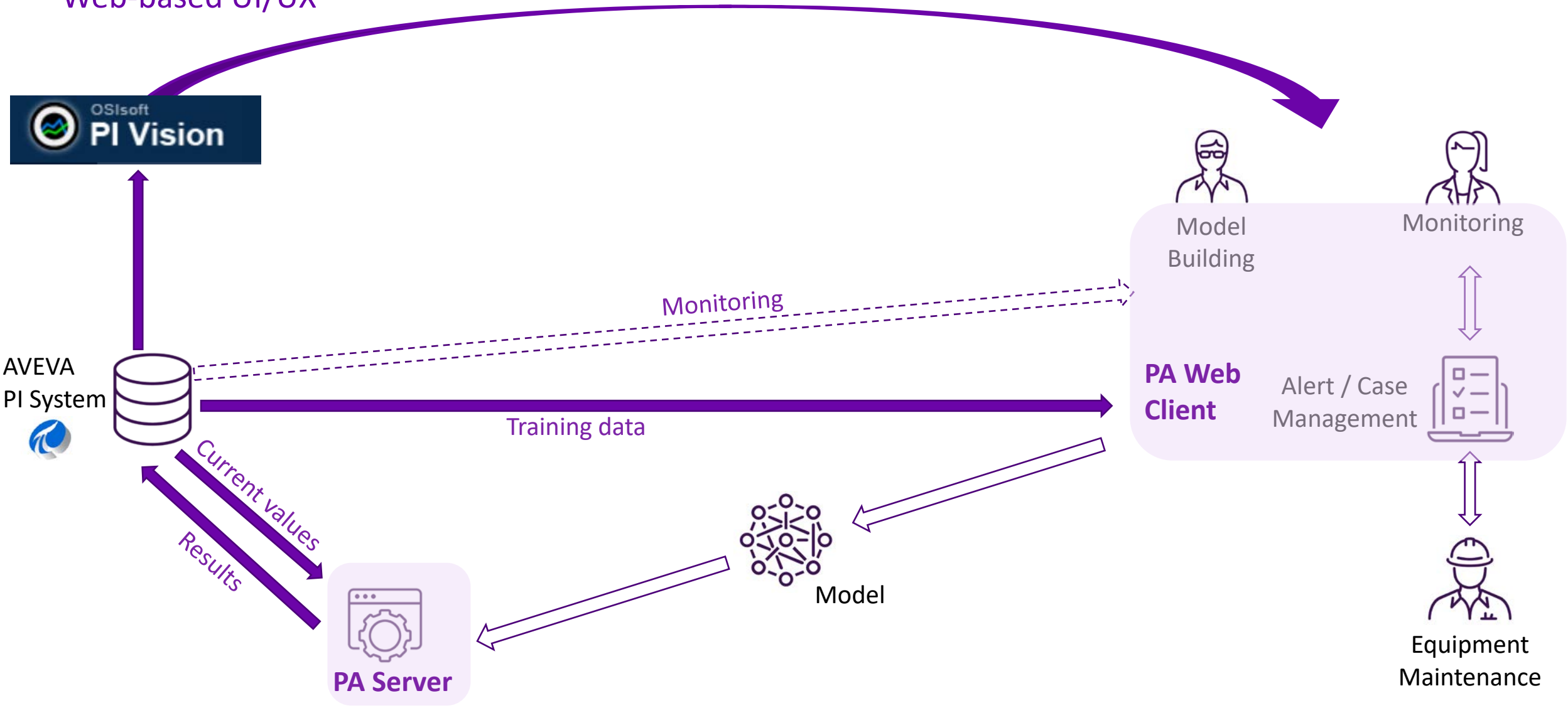


Predictive Analytics – Architecture roadmap

PI System as native Archive Historian

Predictive Analytics – Architecture roadmap

Web-based UI/UX



Demo – Wind farm performance and health monitoring

Windtopia

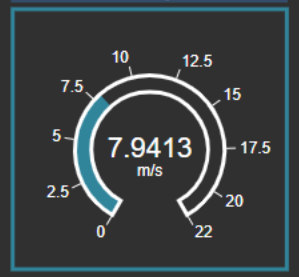
Farm Performance: Big Buffalo Wind Farm

Power Home
Wind Home
Farm Performance
Farm Forecast
Turbine Operations
Turbine Schematic

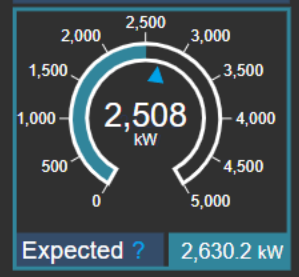
Change Context: Big Buffalo Wind Farm | Black Mesa Wind Farm | Black Wolf Wind Farm

Turbine Summary	
Normal Operation	4
Low Wind	0
High Wind	0
Auto Stop	0
Manual Stop	0
Curtailment	0
Turbines Installed	4

Wind Speed



Active Power

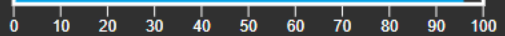


Expected ? 2,630.2 kW

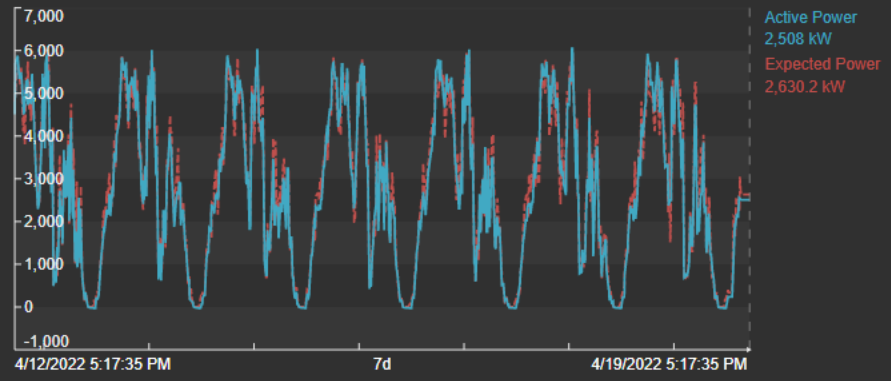
Asset	Wind Speed	Active Power	Production Loss	6h Health
GE01	10.2 m/s	967.0 kW	-328.1 kW	99.2 %
GE02	8.3 m/s	591.0 kW	-68.1 kW	100.0 %
GE03	7.7 m/s	568.0 kW	62.7 kW	99.3 %
GE04	5.5 m/s	382.0 kW	211.3 kW	100.0 %

Capacity Factor 41.8 %

Equivalent Availability (MTD) 95.8



Actual and Expected Power



Underperforming Turbines

GE01
▲ -328 kW
Health 99.2 %

GE02
▲ -68 kW
Health 100.0 %

Windtopia

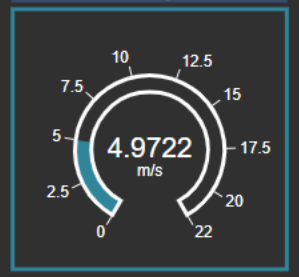
Farm Performance: Black Mesa Wind Farm

Power Home
Wind Home
Farm Performance
Farm Forecast
Turbine Operations
Turbine Schematic

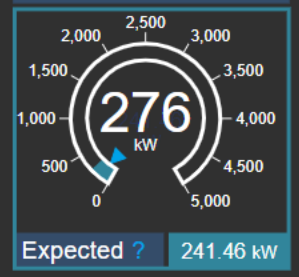
Change Context: Big Buffalo Wind Farm | Black Mesa Wind Farm | Black Wolf Wind Farm

Turbine Summary	
Normal Operation	3
Low Wind	0
High Wind	0
Auto Stop	0
Manual Stop	0
Curtailment	0
Turbines Installed	3

Wind Speed



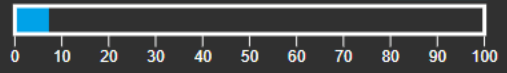
Active Power



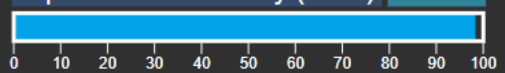
Expected ? 241.46 kW

Asset	Wind Speed	Active Power	Production Loss	6h Health
GE05	5.3 m/s	113.2 kW	-41.5 kW	100.0 %
GE06	5.0 m/s	95.5 kW	-44.1 kW	100.0 %
GE07	4.8 m/s	153.4 kW	-23.6 kW	100.0 %

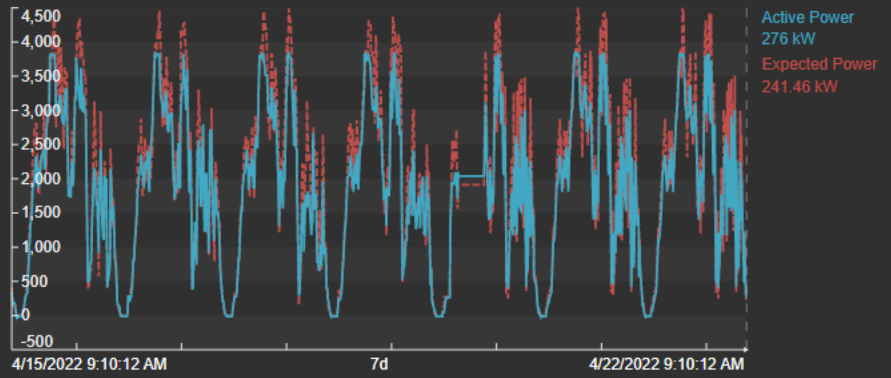
Capacity Factor 7.3 %



Equivalent Availability (MTD) 98.3



Actual and Expected Power



Underperforming Turbines

GE05
▲ -41 kW
Health 100.0 %

GE06
▲ -44 kW
Health 100.0 %

GE07

Windtopia

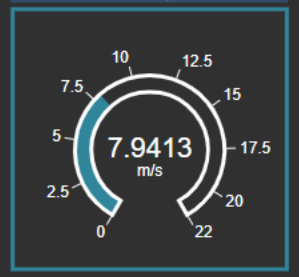
Farm Performance: Big Buffalo Wind Farm

Power Home
Wind Home
Farm Performance
Farm Forecast
Turbine Operations
Turbine Schematic

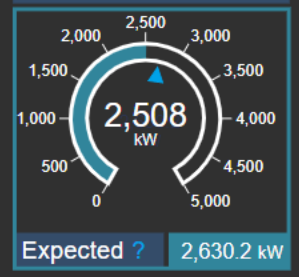
Change Context: Big Buffalo Wind Farm | Black Mesa Wind Farm | Black Wolf Wind Farm

Turbine Summary	
Normal Operation	4
Low Wind	0
High Wind	0
Auto Stop	0
Manual Stop	0
Curtailment	0
Turbines Installed	4

Wind Speed



Active Power

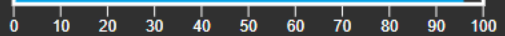


Expected ? 2,630.2 kW

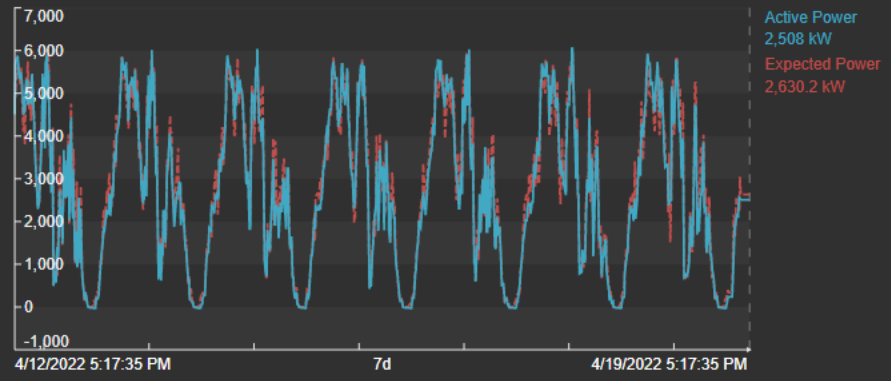
Asset	Wind Speed	Active Power	Production Loss	6h Health
GE01	10.2 m/s	967.0 kW	-328.1 kW	99.2 %
GE02	8.3 m/s	591.0 kW	-68.1 kW	100.0 %
GE03	7.7 m/s	568.0 kW	62.7 kW	99.3 %
GE04	5.5 m/s	382.0 kW	211.3 kW	100.0 %

Capacity Factor 41.8 %

Equivalent Availability (MTD) 95.8



Actual and Expected Power



Underperforming Turbines

GE01
▲ -328 kW
Health 99.2 %

GE02
▲ -68 kW
Health 100.0 %

Windtopia

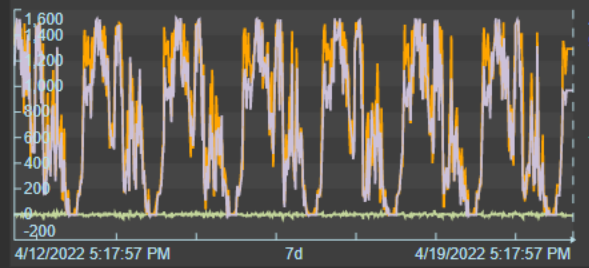
Turbine Operations: Turbine GE01

Power Home
Wind Home
Farm Performance
Farm Forecast
Turbine Operations
Turbine Schematic

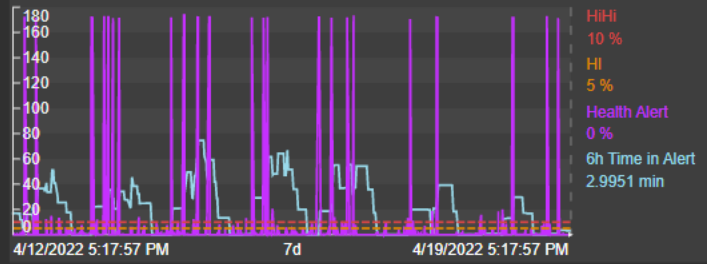
Change Context: GE01 GE02 GE03 GE04 GE05 GE06 GE07 GE08 GE09 GE10

Daily Generation	6.5 kWh1	Capacity	28.8 %	State	Load Operation	Operating Efficiency	74.7 %	Overheat Alarm	

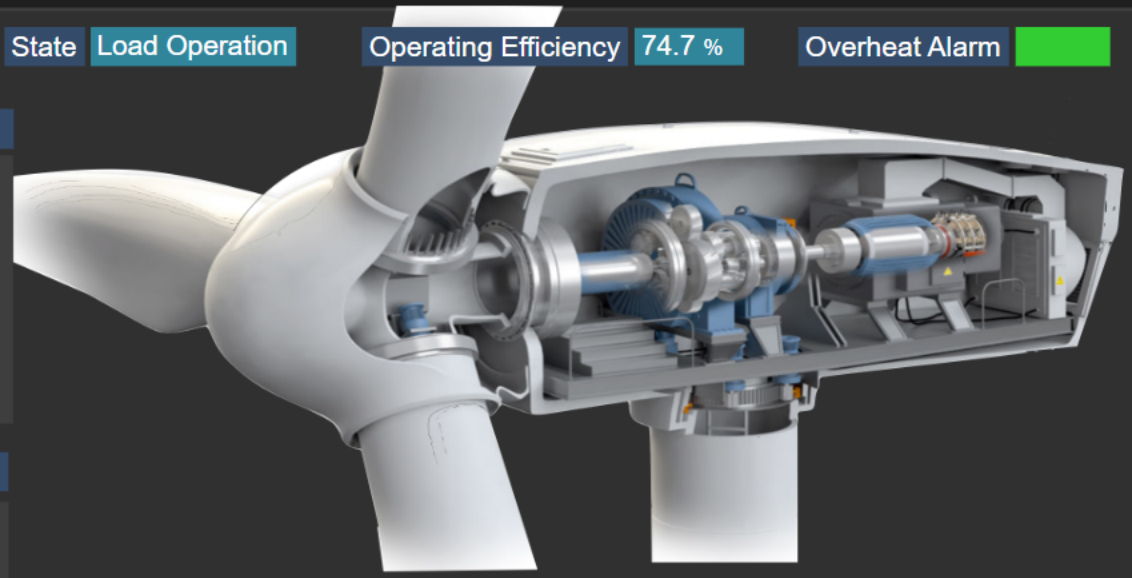
Power Trends



Predictive Health Score



View Alerts in Predictive Analytics

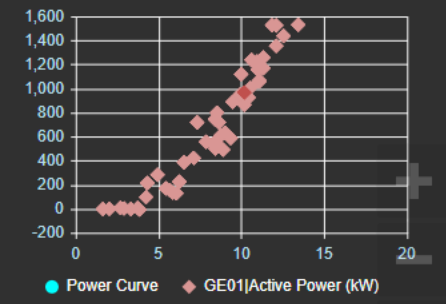


Revenue Loss	Production Loss
-13.74 USD/h	-328.09 kW

Predictive Health Events

Event Name	Start Time	End Time
Predictive Health Alert: GE01 2022-04-12 11:45	4/12/2022 8:45:01 PM	4/12/2022 8:47:16 PM
Predictive Health Alert: GE01 2022-04-12 12:23	4/12/2022 9:23:56 PM	4/12/2022 9:32:21 PM
Predictive Health Alert: GE01	4/12/2022 11:28:16 PM	4/12/2022 11:38:41 PM

Power Curve



Turbine Details

Manufacturer	Truvale
Model	T95-2MW
Power Rated	1,500 kW

AVEVA™ Predictive Analytics

Trends | Faults | Forecast

04/18/2022 17:18 to **04/19/2022 17:18** at **18 Seconds**

Time Span | Auto (Last: 17:18)

1 | Days

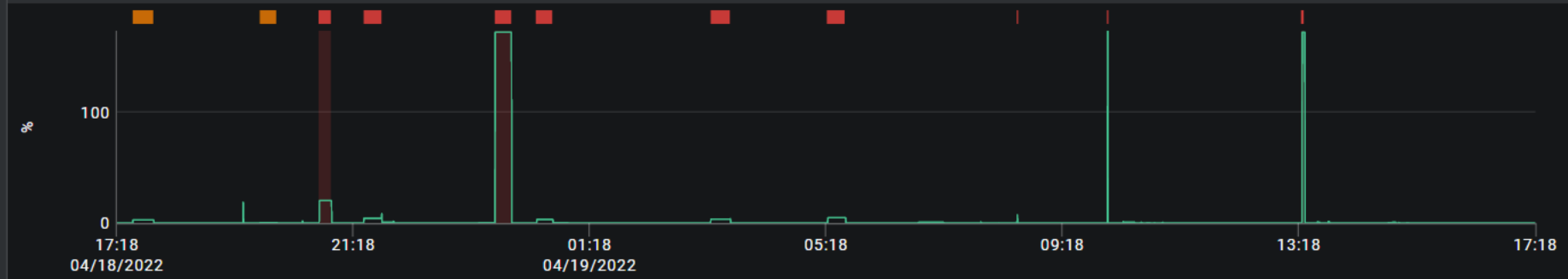
- GE01 Turbine Performance
  - Non-Modeled
    - AMBIENT TEMPERATURE (...
    - ROTOR RPM (GE01.RotorS...
    - POSSIBLE POWER (GE01.G...
  - GE01 Turbine Performance
    - (Overall Model Residual)
    - WIND DIRECTION (GE01.E...
    - WIND SPEED (GE01.Enviro...
    - NACELLE DIRECTION (GE0...
    - ROTOR PITCH ANGLE (GE0...
    - ACTUAL ACTIVE POWER (...

Filters

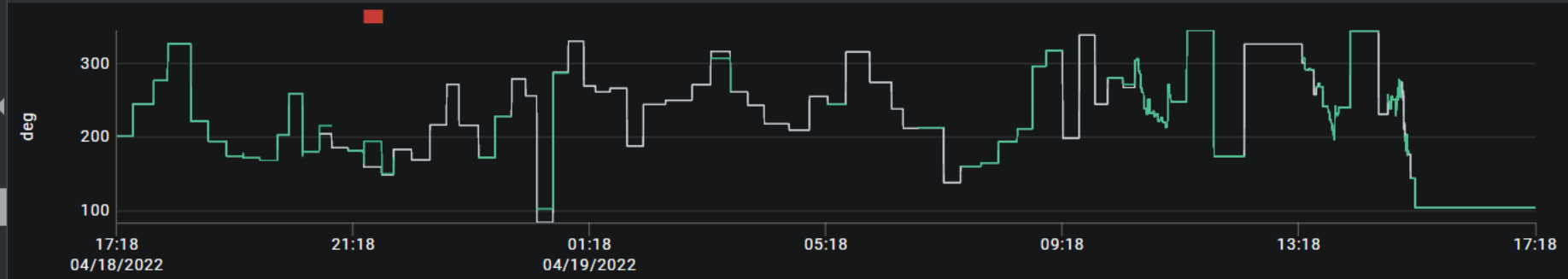
Alerts: Mark

Quality: Mark, Hide

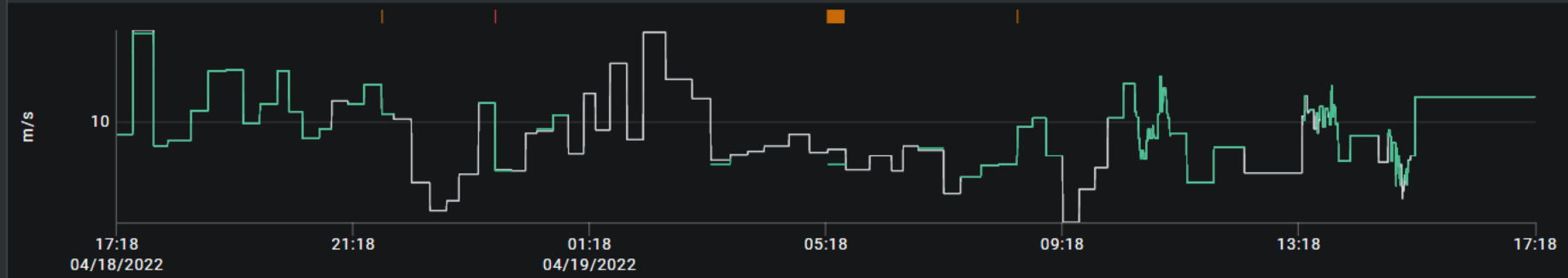
(Overall Model Residual)



WIND DIRECTION (GE01.Environment.Wind Direction)



WIND SPEED (GE01.Environment.Wind Speed)



NACELLE DIRECTION (GE01.Nacelle.Direction Of Nacelle)

AVEVA™ Predictive Analytics

Trends | Faults | Forecast

04/18/2022 17:18 to **04/19/2022 17:18** at **18 Seconds**

Time Span | Auto (Last: 17:18)

1 | Days

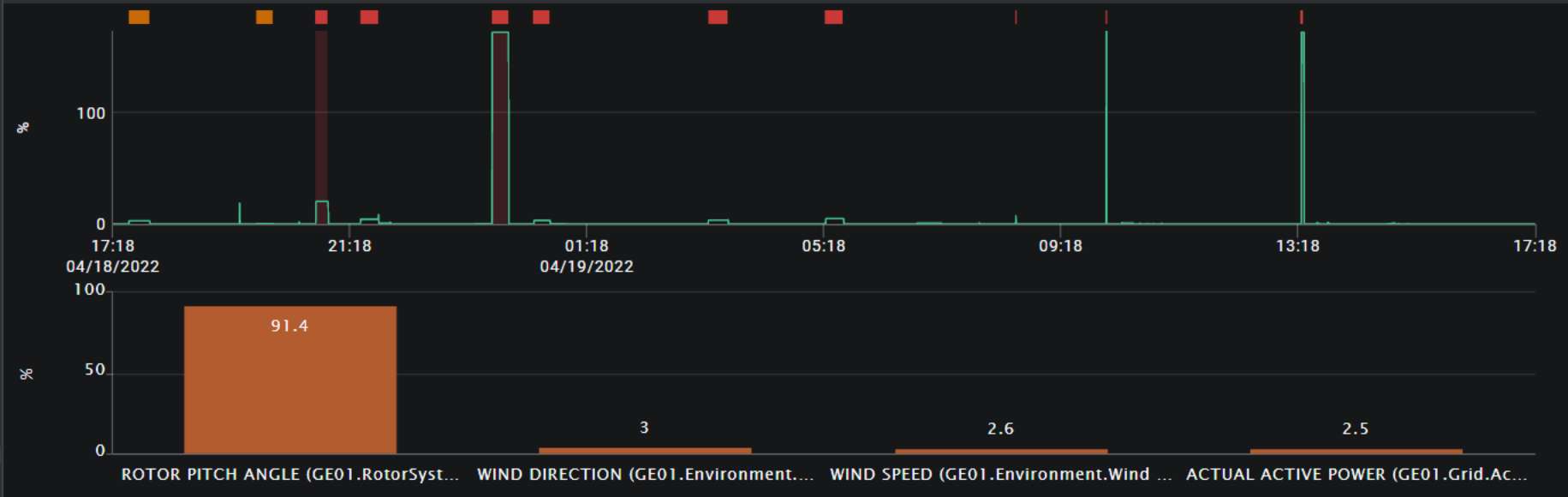
- GE01 Turbine Performance
  - Non-Modeled
    - AMBIENT TEMPERATURE (...
    - ROTOR RPM (GE01.RotorS...
    - POSSIBLE POWER (GE01.G...
  - GE01 Turbine Performance
    - (Overall Model Residual)
    - WIND DIRECTION (GE01.E...
    - WIND SPEED (GE01.Enviro...
    - NACELLE DIRECTION (GE0...
    - ROTOR PITCH ANGLE (GE0...
    - ACTUAL ACTIVE POWER (...

Filters

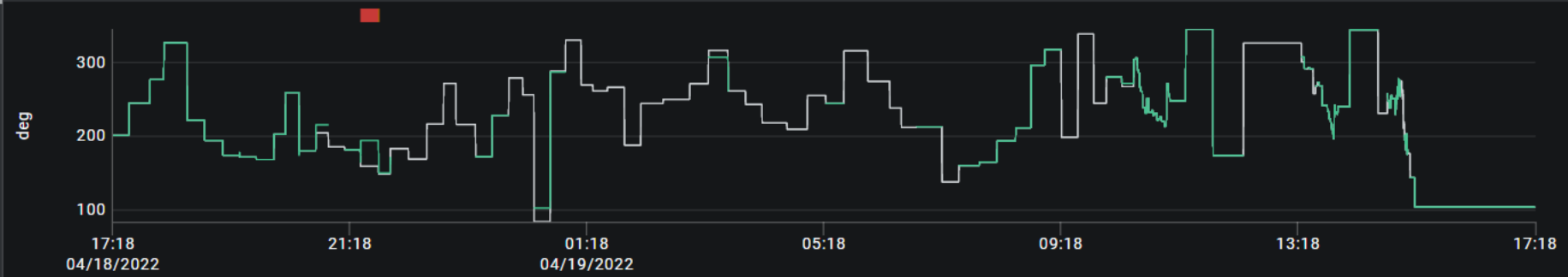
Alerts: Mark

Quality: Mark, Hide

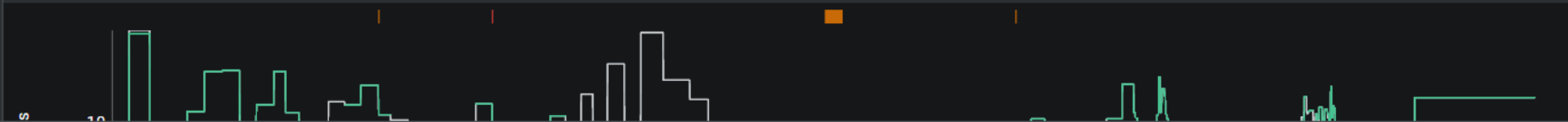
(Overall Model Residual)



WIND DIRECTION (GE01.Environment.Wind Direction)



WIND SPEED (GE01.Environment.Wind Speed)



AVEVA™ Predictive Analytics

Trends | Faults | Forecast

04/18/2022 17:18 to **04/19/2022 17:18** at **18 Seconds**

Time Span | Auto (Last: 17:18)

1 | Days

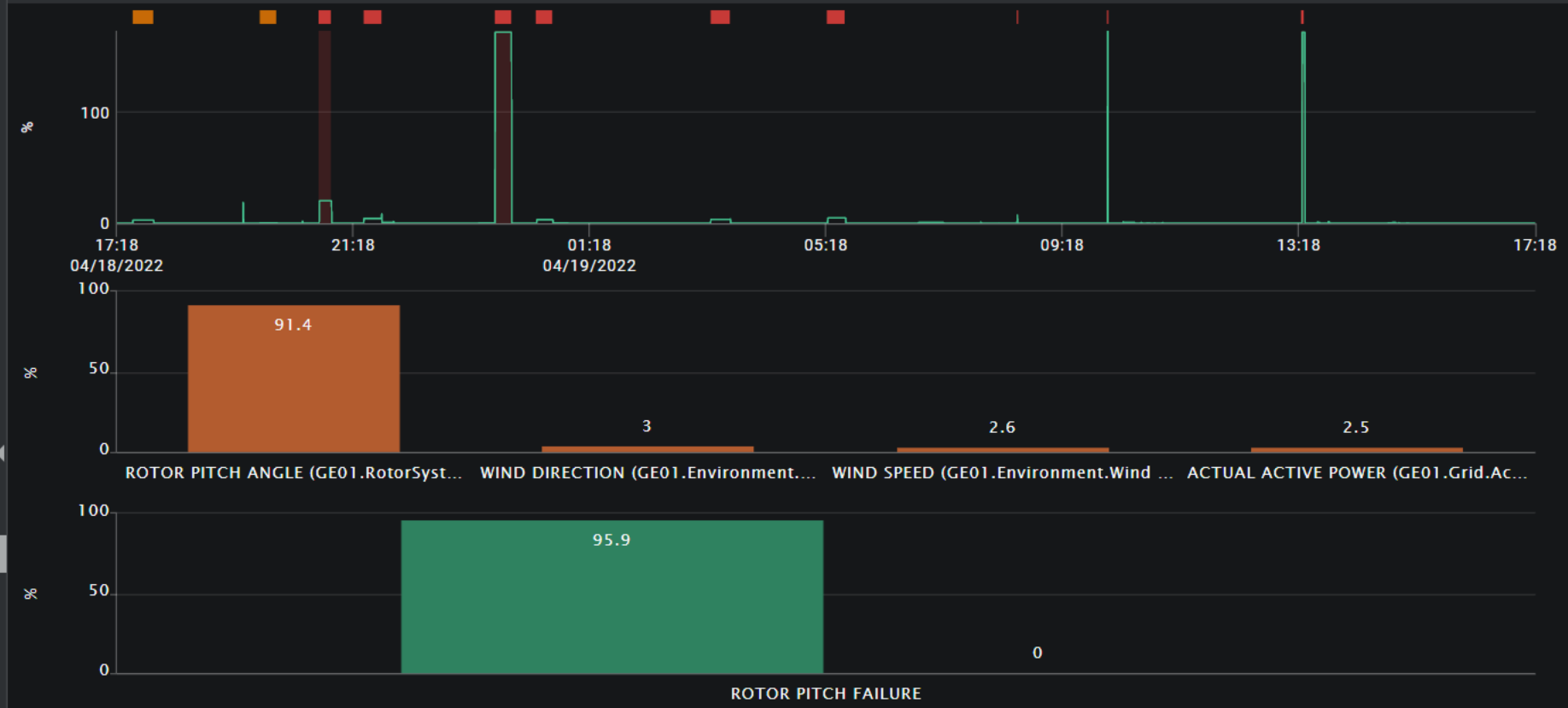
- GE01 Turbine Performance
  - Non-Modeled
    - AMBIENT TEMPERATURE (...
    - ROTOR RPM (GE01.RotorS...
    - POSSIBLE POWER (GE01.G...
  - GE01 Turbine Performance
    - (Overall Model Residual)
    - WIND DIRECTION (GE01.E...
    - WIND SPEED (GE01.Enviro...
    - NACELLE DIRECTION (GE0...
    - ROTOR PITCH ANGLE (GE0...
    - ACTUAL ACTIVE POWER (...

Filters

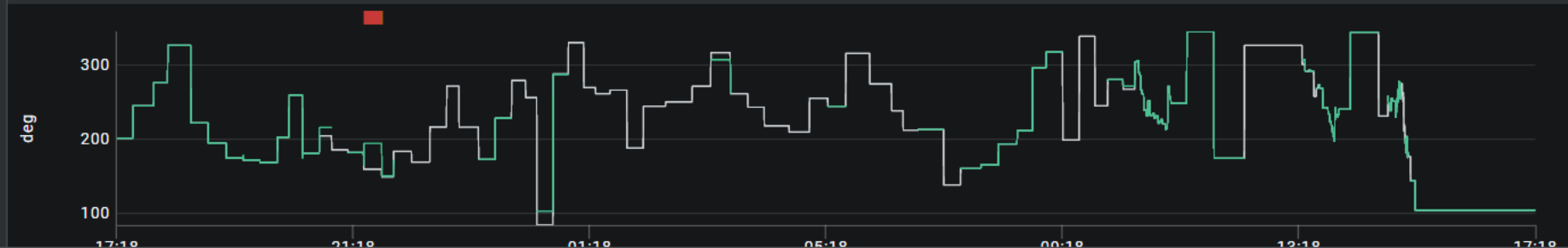
Alerts: Mark

Quality: Mark, Hide

(Overall Model Residual)



WIND DIRECTION (GE01.Environment.Wind Direction)



AVEVA™ Predictive Analytics

Trends | Faults | Forecast

04/18/2022 17:18 to **04/19/2022 17:18** at **5 Seconds**

Time Span — Auto (Last: 17:18)

1 | Days

GE01 Turbine Performance

ROTOR PITCH FAILURE	95.9%
YAW FAILURE	0.8%

Fault Diagnostics: Threshold, Mark

Filters: Hide

Alerts

Quality: Hide

ROTOR PITCH FAILURE

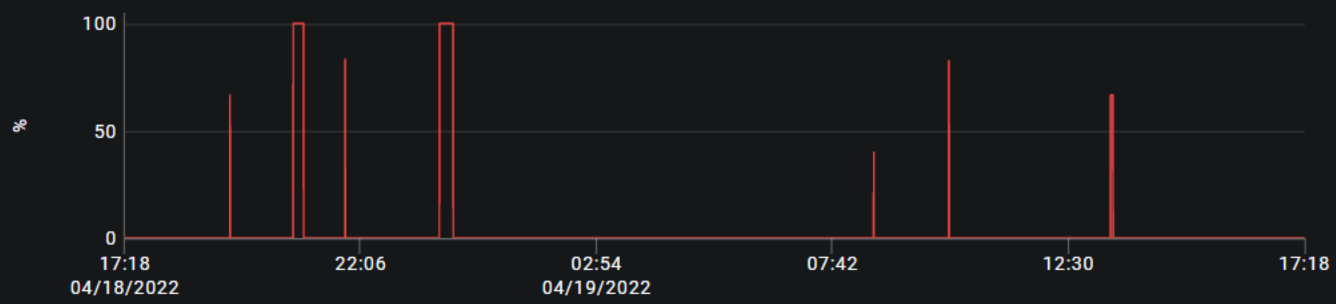
DESCRIPTION

Rotor pitch angle has deviated from expected pitch angle for the current wind speed. Reasons could be:
1) Control system action to protect turbine
2) Control system malfunction

NEXT STEPS

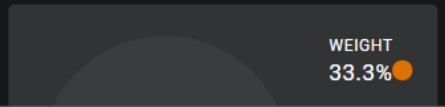
1) Operational - Verify turbine within safe operating limits for wind speed & turbulence. Stop turbine if safety limits exceed.
2) Operational - Verify turbine within overall self

USER DEFINED PROPERTIES



Fault signature - ROTOR PITCH ANGLE

Fault signature - WIND SPEED



AVEVA™ Predictive Analytics

Trends | Faults | Forecast

04/18/2022 17:18 to **04/19/2022 17:18** at **18 Seconds**

Time Span | Auto (Last: 17:18)

1 | Days

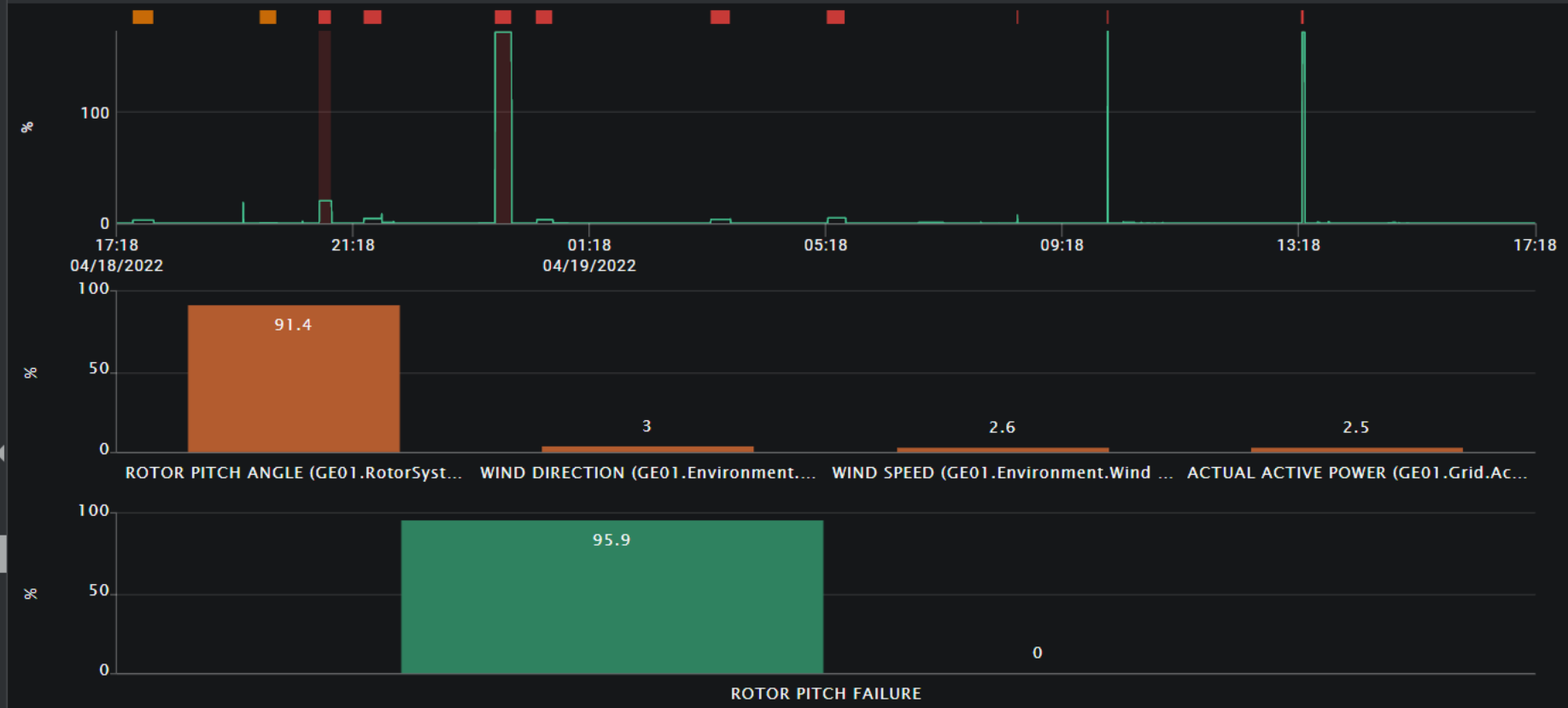
- GE01 Turbine Performance
  - Non-Modeled
    - AMBIENT TEMPERATURE (...
    - ROTOR RPM (GE01.RotorS...
    - POSSIBLE POWER (GE01.G...
  - GE01 Turbine Performance
    - (Overall Model Residual)
    - WIND DIRECTION (GE01.E...
    - WIND SPEED (GE01.Enviro...
    - NACELLE DIRECTION (GE0...
    - ROTOR PITCH ANGLE (GE0...
    - ACTUAL ACTIVE POWER (...

Filters

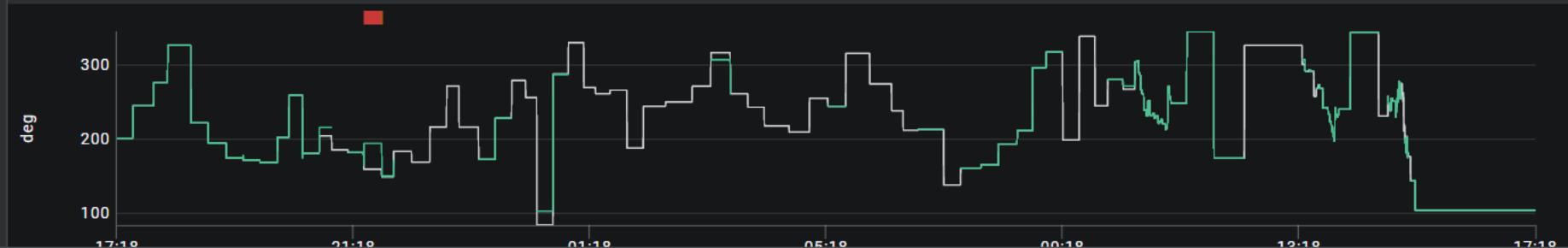
Alerts: Mark

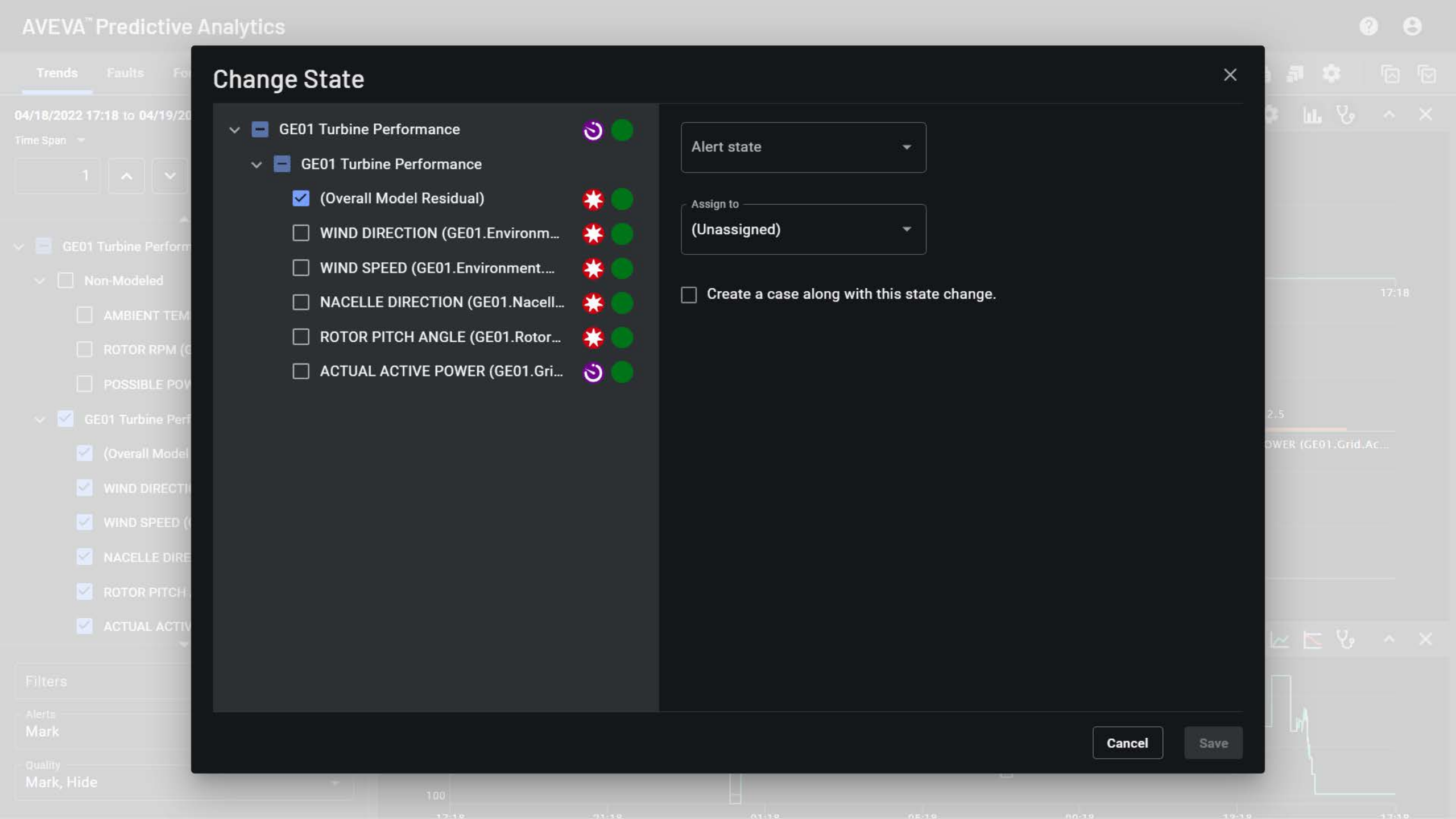
Quality: Mark, Hide

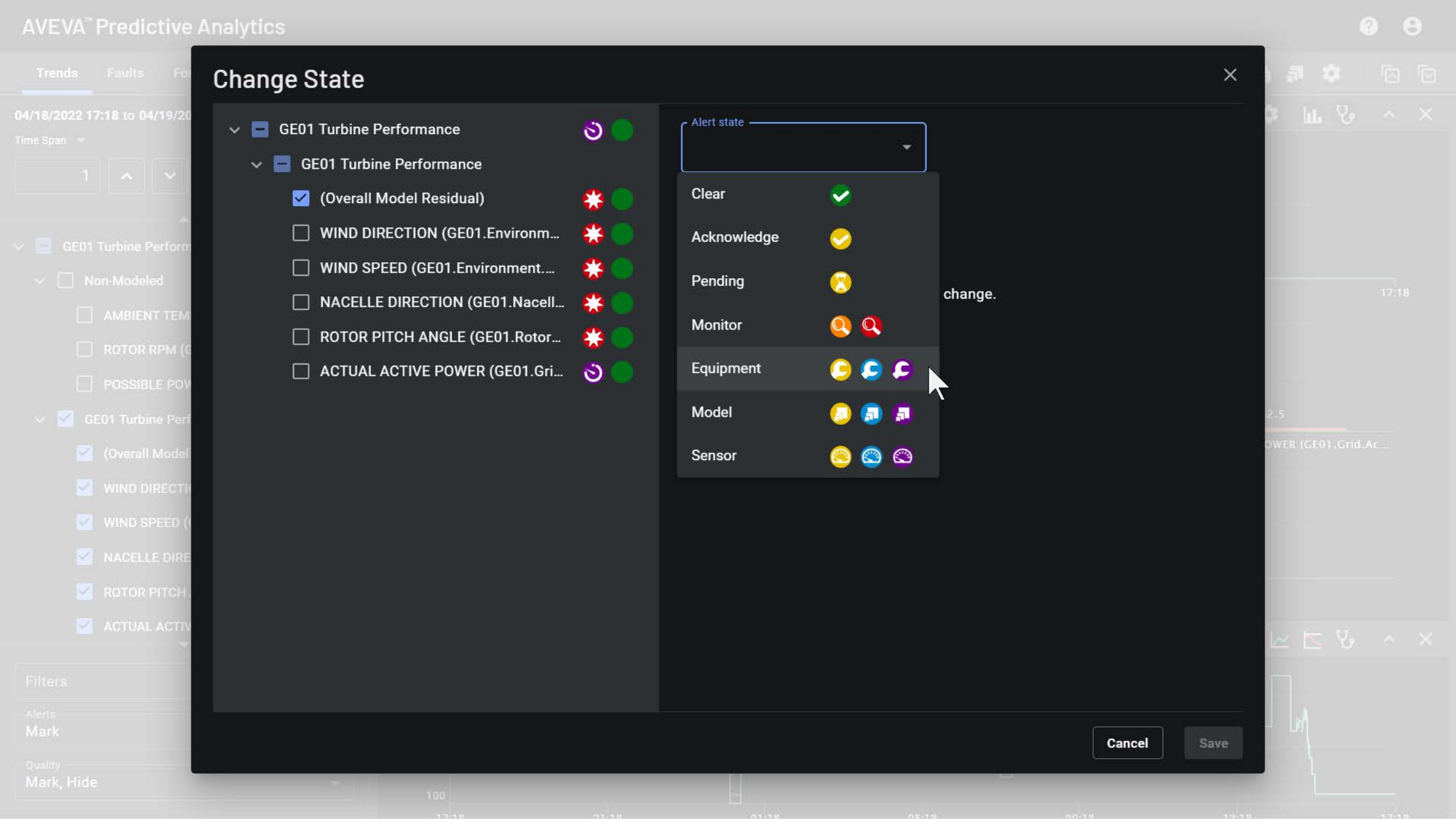
(Overall Model Residual)

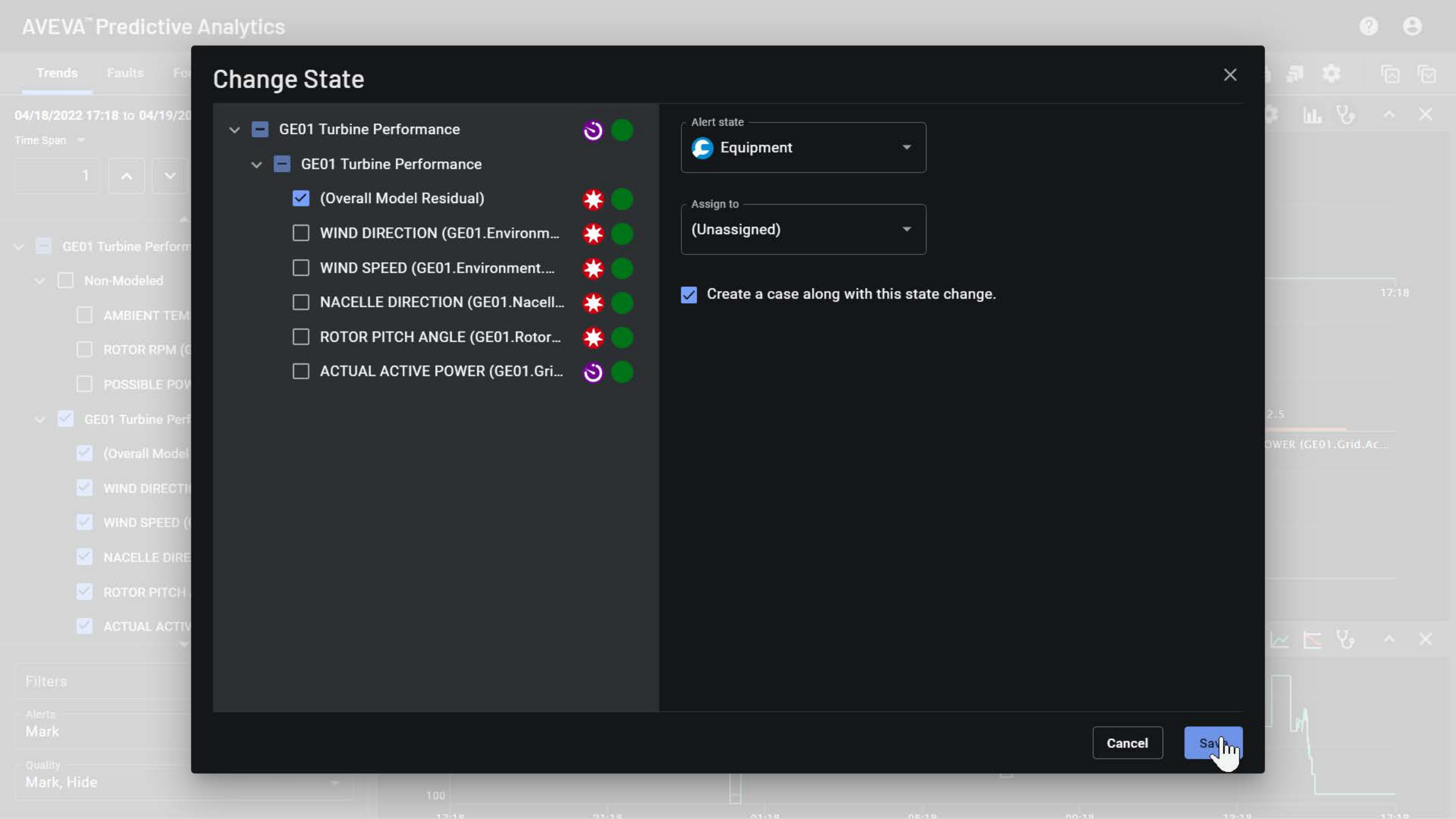


WIND DIRECTION (GE01.Environment.Wind Direction)




AVEVA™ Predictive Analytics
Trends
Faults
Change State
GE01 Turbine Performance
GE01 Turbine Performance
(Overall Model Residual)
WIND DIRECTION (GE01.Environm...
WIND SPEED (GE01.Environment....
NACELLE DIRECTION (GE01.Nacell...
ROTOR PITCH ANGLE (GE01.Rotor...
ACTUAL ACTIVE POWER (GE01.Gri...
Alert state
Assign to
(Unassigned)
Create a case along with this state change.
Cancel
Save


AVEVA™ Predictive Analytics
Trends
Faults
Change State
GE01 Turbine Performance
GE01 Turbine Performance
(Overall Model Residual)
WIND DIRECTION (GE01.Environm...
WIND SPEED (GE01.Environment....
NACELLE DIRECTION (GE01.Nacell...
ROTOR PITCH ANGLE (GE01.Rotor...
ACTUAL ACTIVE POWER (GE01.Gri...
Alert state
Clear
Acknowledge
Pending
Monitor
Equipment
Model
Sensor
change.
Cancel
Save


AVEVA™ Predictive Analytics
Trends
Faults
Change State
GE01 Turbine Performance
GE01 Turbine Performance
(Overall Model Residual)
WIND DIRECTION (GE01.Environm...
WIND SPEED (GE01.Environment....
NACELLE DIRECTION (GE01.Nacell...
ROTOR PITCH ANGLE (GE01.Rotor...
ACTUAL ACTIVE POWER (GE01.Gri...
Alert state
Equipment
Assign to
(Unassigned)
Create a case along with this state change.
Cancel
Save

Case ID: 2020

Title: Rotor pitch angle deviation

Description: Please check control system and rotor pitch actuation

Case state: Open

Priority: Normal

Category: Mechanical

Anomaly start: 04/18/2022 05:25 pm

Anomaly end

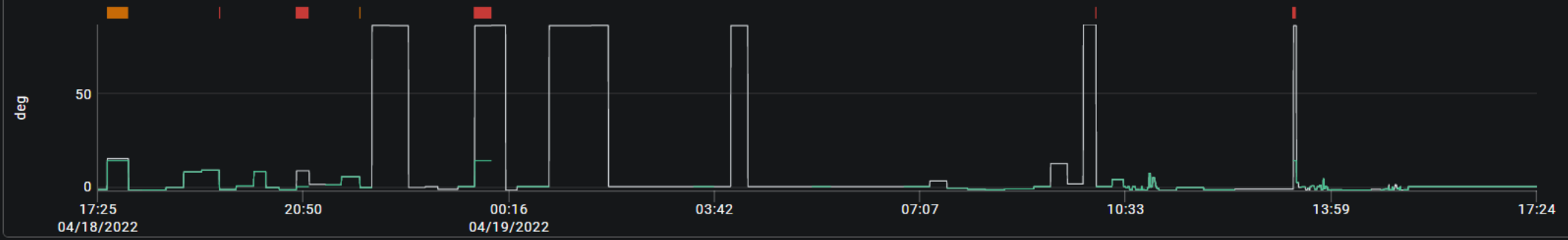
External ID

Assigned to: SiteOperator

Trends | Discussions | Projects | Links | Resolution | Revision history

Snapshot by **AvevaUser** in time zone **(UTC+01:00) Brussels, Copenhagen, Madrid, Paris** at **04/19/2022 05:26:41 PM**

ROTOR PITCH ANGLE (GE01.RotorSystem.Pitch Angle)



Cancel | Save

Case ID: 2020

Title
Rotor pitch angle deviation

Description
Please check control system and rotor pitch actuation

Case state
Open

Open
Closed

Category
Mechanical

Anomaly start
04/18/2022 05:25 pm

Anomaly end

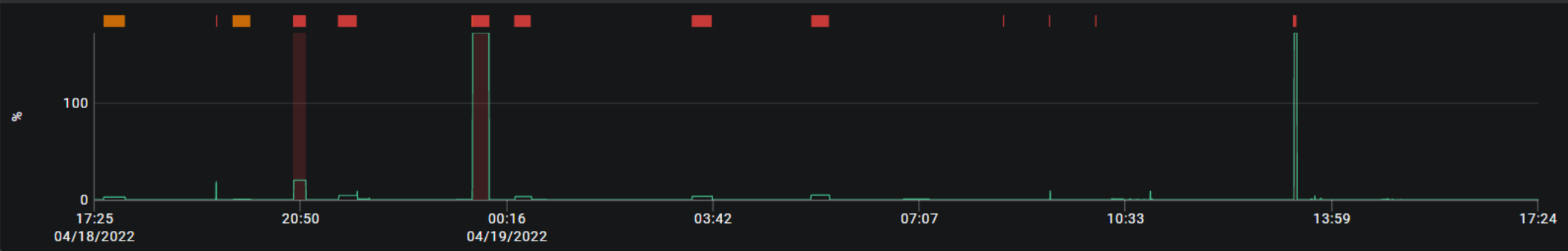
External ID

Assigned to
SiteOperator

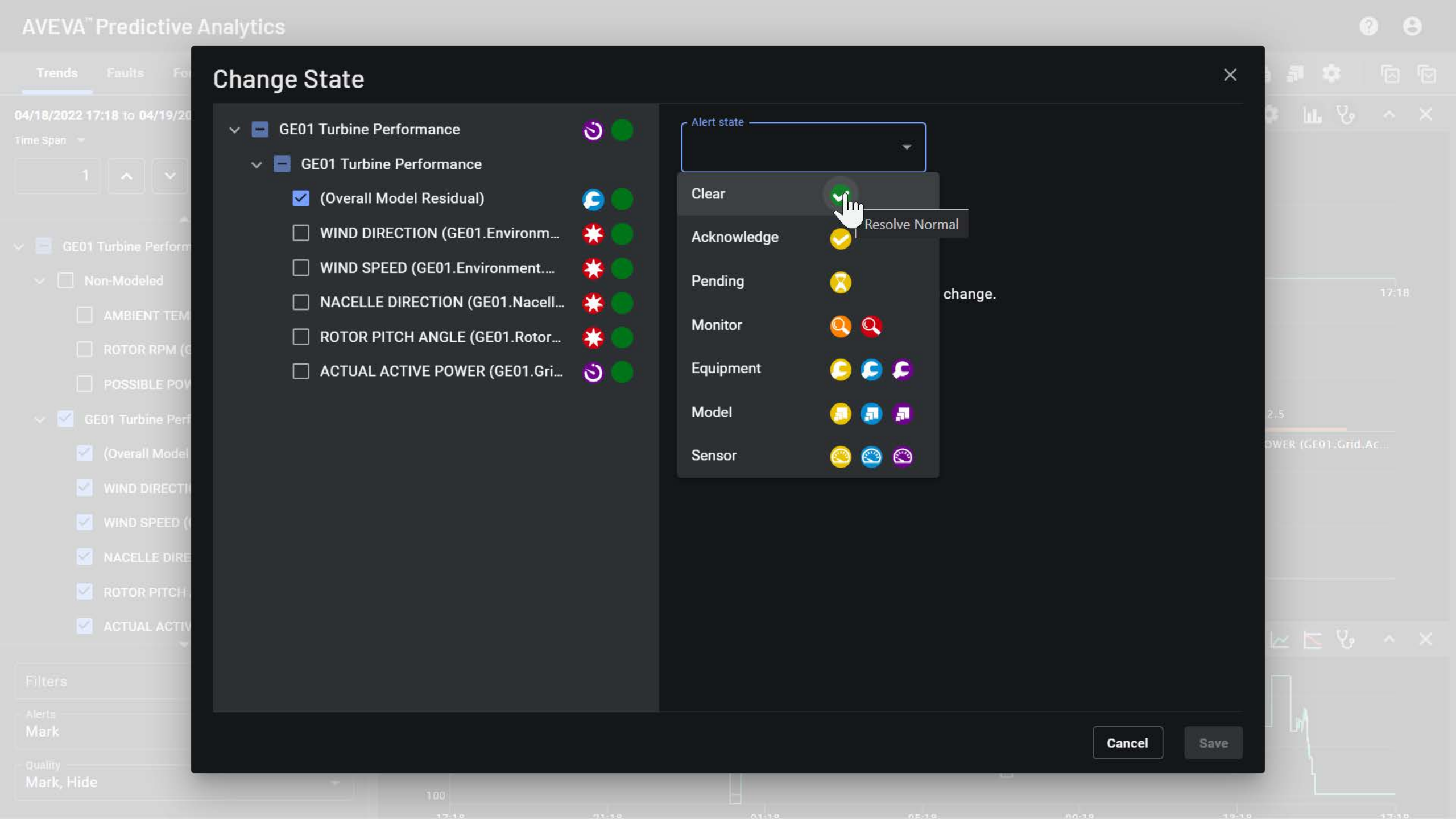
Trends | Discussions | Projects | Links | Resolution | Revision history

Snapshot by **AvevaUser** in time zone **(UTC+01:00) Brussels, Copenhagen, Madrid, Paris** at **04/19/2022 05:26:41 PM**

(Overall Model Residual)



Cancel | Save


AVEVA™ Predictive Analytics
Trends
Faults
Change State
GE01 Turbine Performance
GE01 Turbine Performance
(Overall Model Residual)
WIND DIRECTION (GE01.Environm...
WIND SPEED (GE01.Environment....
NACELLE DIRECTION (GE01.Nacell...
ROTOR PITCH ANGLE (GE01.Rotor...
ACTUAL ACTIVE POWER (GE01.Gri...
Alert state
Clear
Resolve Normal
Acknowledge
Pending
Monitor
Equipment
Model
Sensor
change.
Cancel
Save

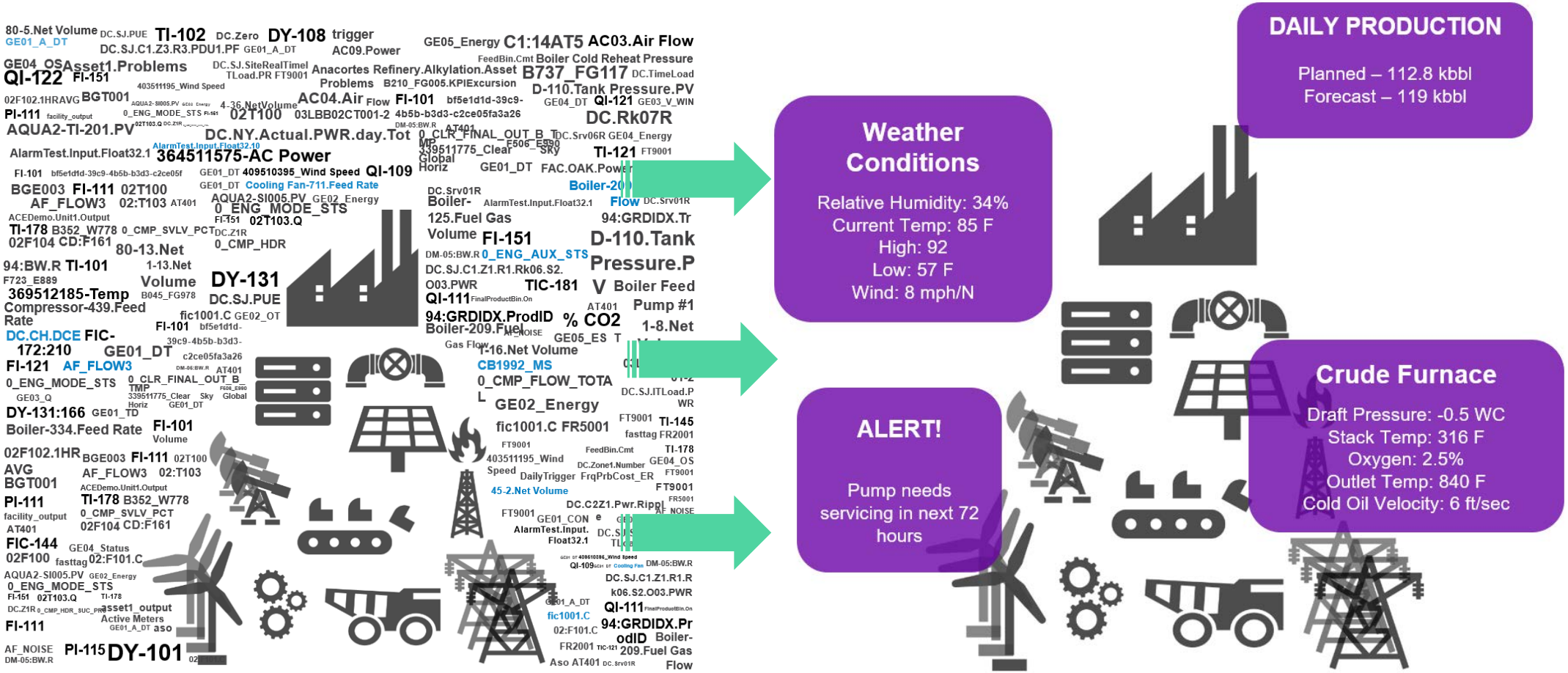
Demo – Wind farm performance and health monitoring

- Monitoring an asset fleet
- Examining an underperforming asset
- Analyzing an alert
- Managing a case

Leveraging Asset Framework in AVEVA Predictive Analytics

Predictive Analytics is integrated with Asset Framework

Effective enterprise data modelling



AVEVA Predictive Analytics workflow

1. Create System Metrics
2. Create a Project Template
3. **Create a Project based on a Project Template ----- AF helps here**
4. Import and clean training data
5. Train the model and obtain the Operational Profile
6. Deploy the model (runtime)
7. **Visualize alerts and manage cases ----- AF helps here**

AVEVA

AVEVA™ Predictive Analytics

Trends | Forecast

04/04/2022 15:47 to 04/05/2022 15:47 at 60 Seconds

Time Span | Auto (Last: 15:47)

24 | Hours

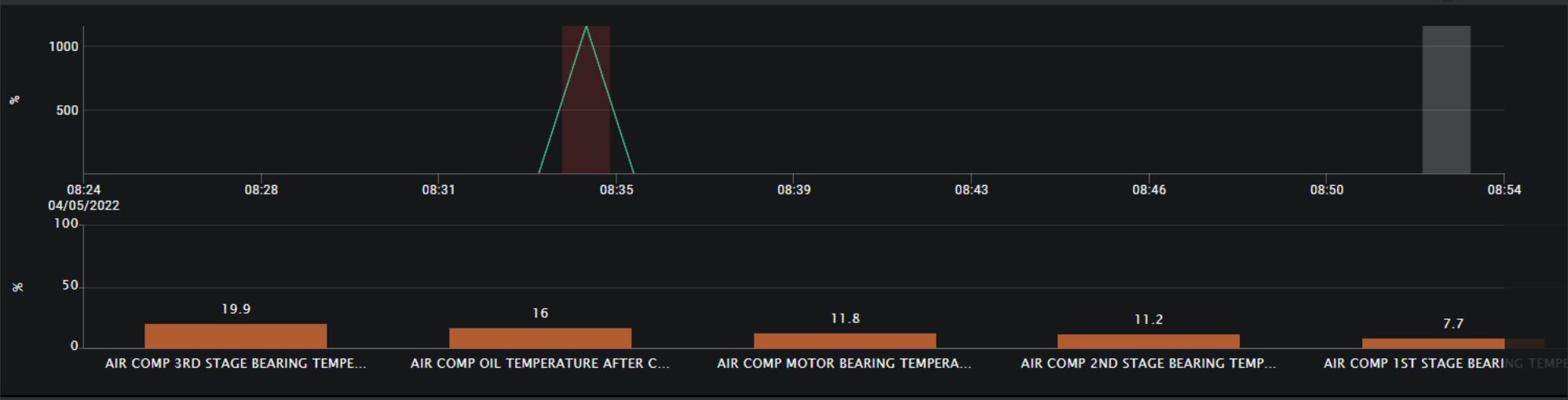
- Compressor01 - AF referenced
  - Compressor01 - AF referenced
    - (Overall Model Residual)
    - AIR COMP 1ST STAGE BEA...
    - AIR COMP 1ST STAGE BEA...
    - AIR COMP 1ST STAGE SUC...
    - AIR COMP 2ND STAGE BE...
    - AIR COMP 2ND STAGE BE...
    - AIR COMP 3RD STAGE BEA...
    - AIR COMP 3TH STAGE BE...
    - AIR COMP 4TH STAGE BE...
    - AIR COMP 4TH STAGE BE...
    - AIR COMP DISCHARGE TE...
    - AIR COMP MAIN SHAFT A...
    - AIR COMP MOTOR BEARIN...
    - AIR COMP MOTOR BEARIN...
    - AIR COMP OIL TEMPERAT...

Filters: Mark, Hide

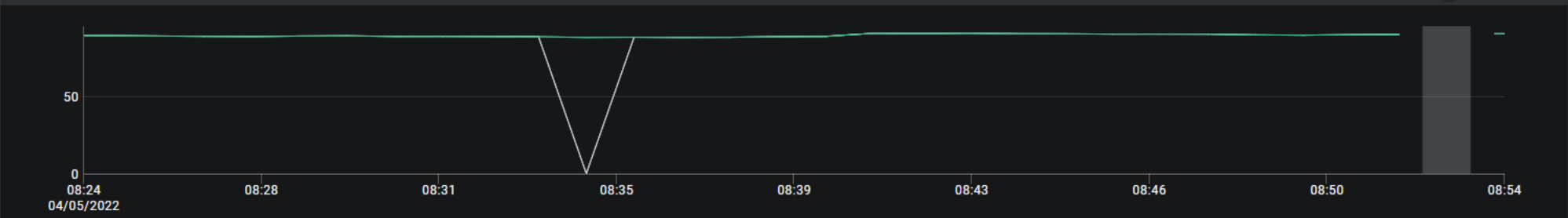
Alerts: Mark

Quality: Mark, Hide

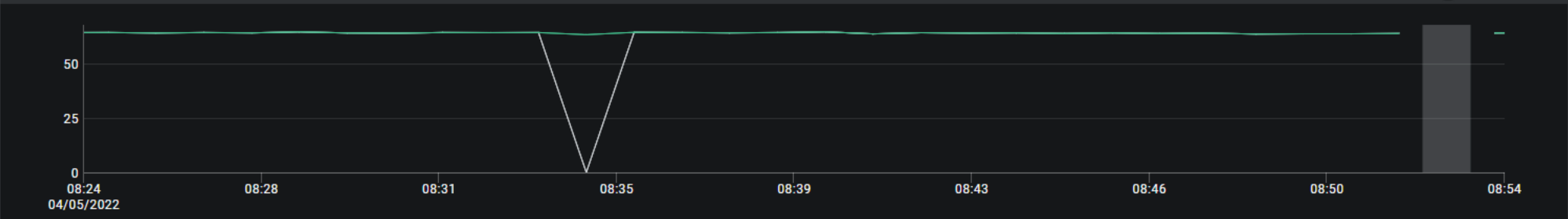
(Overall Model Residual)



AIR COMP 3RD STAGE BEARING TEMPERATURE (\\GCATTARIN-PISRV\Compressors Monitoring\Compressor01|AIR COMP 3RD STAGE BEARI...

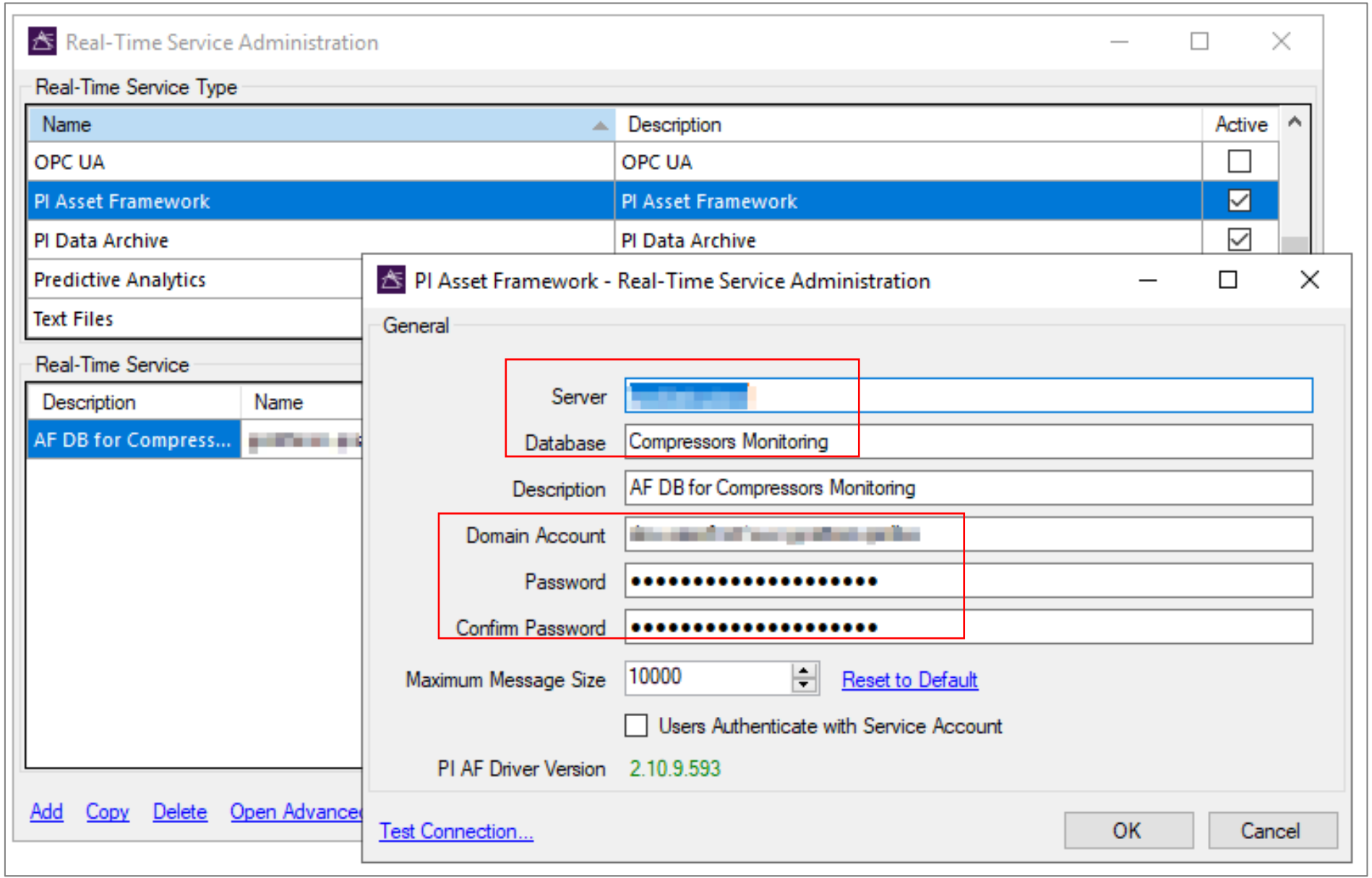


AIR COMP MOTOR BEARING TEMPERATURE NON DRIVE END (\\GCATTARIN-PISRV\Compressors Monitoring\Compressor01|AIR COMP MOT...



AIR COMP OIL TEMPERATURE AFTER COOLER (\\GCATTARIN-PISRV\Compressors Monitoring\Compressor01|AIR COMP OIL TEMPERATURE ...

Real-Time Service Administration



Model Building

Subject to change!

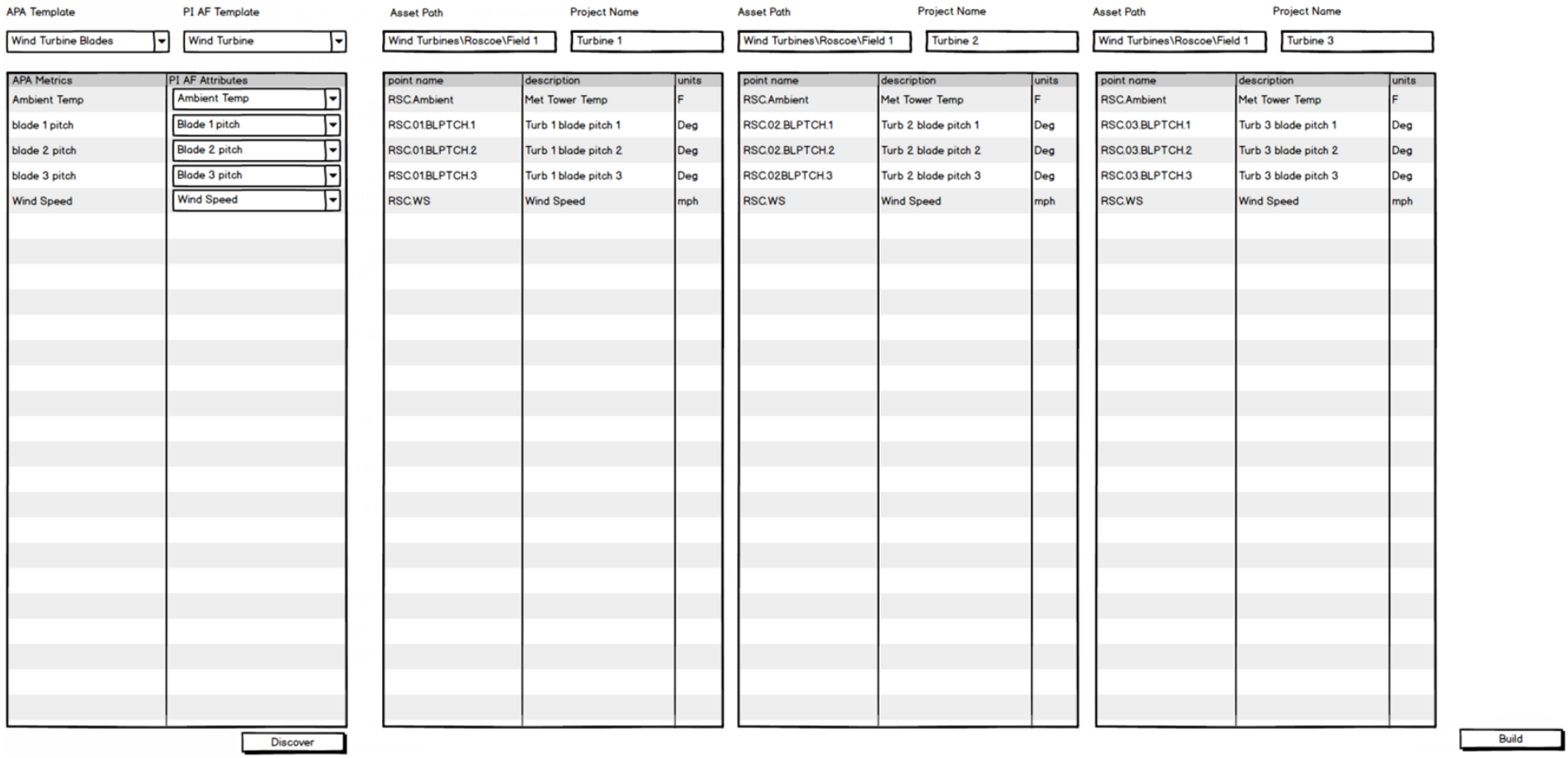
Automated Model Building (PI AF) 2023

Map PA template metrics to AF Template attributes

- Tool will discover:
  - Assets using template
  - Tags for each attribute
- User can adjust list of assets and attributes
- Tool will:
  - Create Model
  - Import training data
  - Cleanse outliers
  - Deploy Profile

Benefits:

- **Save model building time**
- **Minimize errors**
- **Shorten time to value**



Leveraging Asset Framework in AVEVA Predictive Analytics

- Selecting Project Points
- Monitoring Alerts – AF path reference
- Configuring the Real-Time Service connected to Asset Framework
- Roadmap 2023

Key Takeaways

- **Early anomaly detection – end your unplanned downtime**
- Seamless experience **from asset monitoring to alert management**
- Rapidly scale your **model creation** with Asset Framework

… **More to come!**

Francesco Petrone

Senior Technical Solutions Engineer, AVEVA Predictive Analytics

- AVEVA
- francesco.petrone@aveva.com

Giulio Cattarin

Pre-Sales Engineer, AVEVA

- AVEVA
- giulio.cattarin@aveva.com (LinkedIn)

This presentation may include predictions, estimates, intentions, beliefs and other statements that are or may be construed as being forward-looking. While these forward-looking statements represent our current judgment on what the future holds, they are subject to risks and uncertainties that could result in actual outcomes differing materially from those projected in these statements. No statement contained herein constitutes a commitment by AVEVA to perform any particular action or to deliver any particular product or product features. Readers are cautioned not to place undue reliance on these forward-looking statements, which reflect our opinions only as of the date of this presentation.

The Company shall not be obliged to disclose any revision to these forward-looking statements to reflect events or circumstances occurring after the date on which they are made or to reflect the occurrence of future events.

linkedin.com/company/aveva

@avevagroup

ABOUT AVEVA

AVEVA is a global leader in industrial software, driving digital transformation and sustainability. By connecting the power of information and artificial intelligence with human insight, AVEVA enables teams to use their data to unlock new value. We call this Performance Intelligence. AVEVA's comprehensive portfolio enables more than 20,000 industrial enterprises to engineer smarter, operate better and drive sustainable efficiency. AVEVA supports customers through a trusted ecosystem that includes 5,500 partners and 5,700 certified developers around the world. The company is headquartered in Cambridge, UK, with over 6,500 employees and 90 offices in over 40 countries.

Learn more at www.aveva.com

AVEVA