PI World 2020 Online – Q&A

Usage-based, Condition-based and Predictive Maintenance – a Layered Approach

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Summary

Usage-based, Condition-based and Predictive Maintenance – A layered approach

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Attend this session to learn about a layered approach to maintenance as we walk through scenarios to illustrate the combined use of process data and machine condition data for usage-based, condition-based and predictive maintenance. Data sources include traditional plant instrumentation such as PLCs and SCADA, the newer IoT devices, and from machine condition monitoring sources such as vibration, oil analysis etc.

Usage-based maintenance includes using operational metrics such as motor run-hours, compressor start/stops, grinder tonnage etc. And, condition-based maintenance utilizes measurements such as filter deltaP, bearing temperature, valve stroke travel, and others. Predictive maintenance can be using simple analytics such as monitoring vibration (rms, peak etc.) to predict RUL (remaining useful life) or heat-exchanger fouling to schedule cleaning etc. And, the talk will also reference and discuss predictive maintenance use cases that require advanced analytics such as APR (advanced pattern recognition), anomaly detection, and others.

While the talk is vendor neutral, it will include references to the OSIsoft PI System functions/capabilities from end user testimonials.

Takeaways – layered analytics - usage-based, condition-based and predictive maintenance

- Combined machine condition & process data
  - machine - vibration, thermography, oil analysis, ….
  - process - pressure, flow, voltage, amperage…
- Layered Analytics

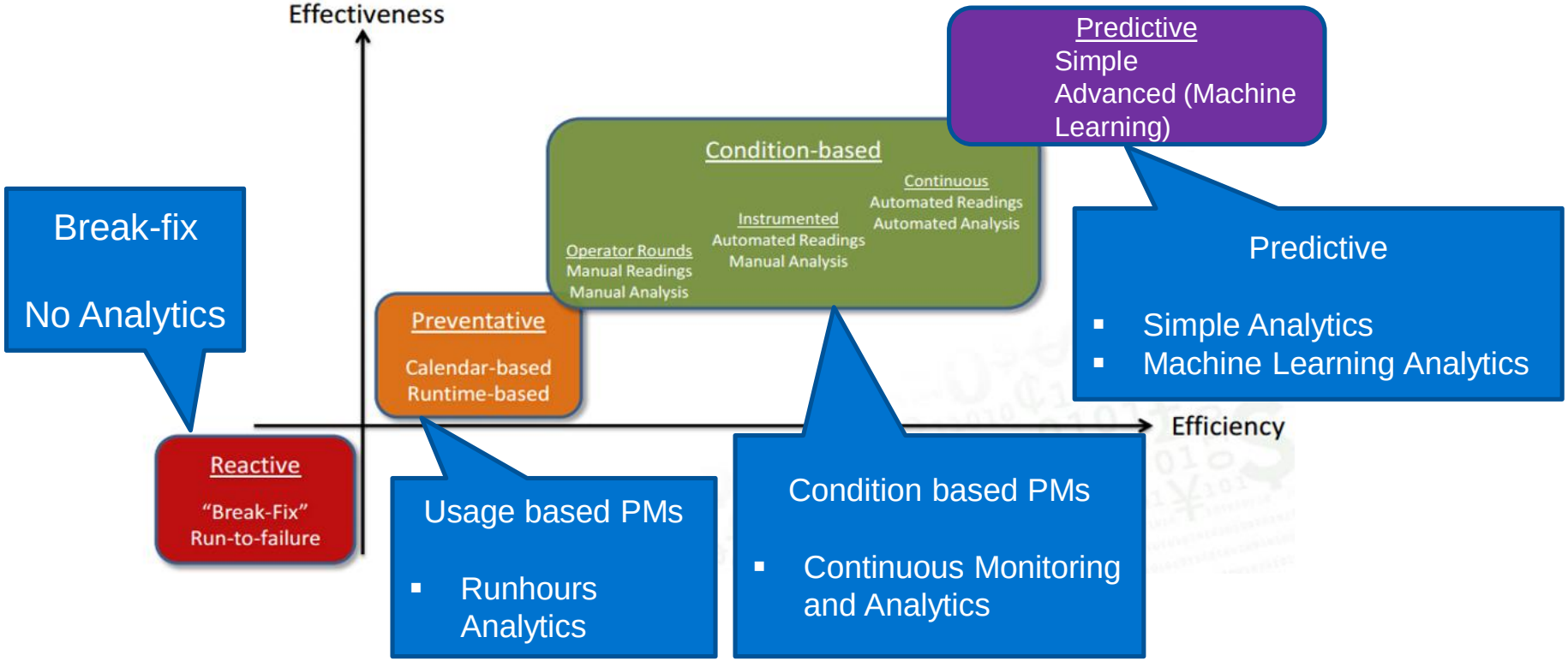
order of magnitude number of models (actual)

  - Usage assessment - counter
    - fan run-hours, pulverizer tonnage, motor starts/stops, … ~1000s (2000)
  - Condition assessment - machine and/or process
    - low motor efficiency, high vibration, high filter DP, fouled heat-exchanger… ~10000s (30000)
  - Predictive - Simple - extrapolate trend to predict remaining useful life (RUL) ~1000s (3000)
    - rate of change, piecewise linear, logarithmic, curve-fit, steam-tables, table look-up…
  - Predictive - Advanced – machine learning, APR etc. – anomaly, early failure… ~100s (300) R/Python/Other
  - Asset Health Score - weighted sum of scores of many condition indicators ~100s (300)
    - distribution transformer - LTC (load tap changer) count, DGA (dissolved gas), nitrogen pressure, …

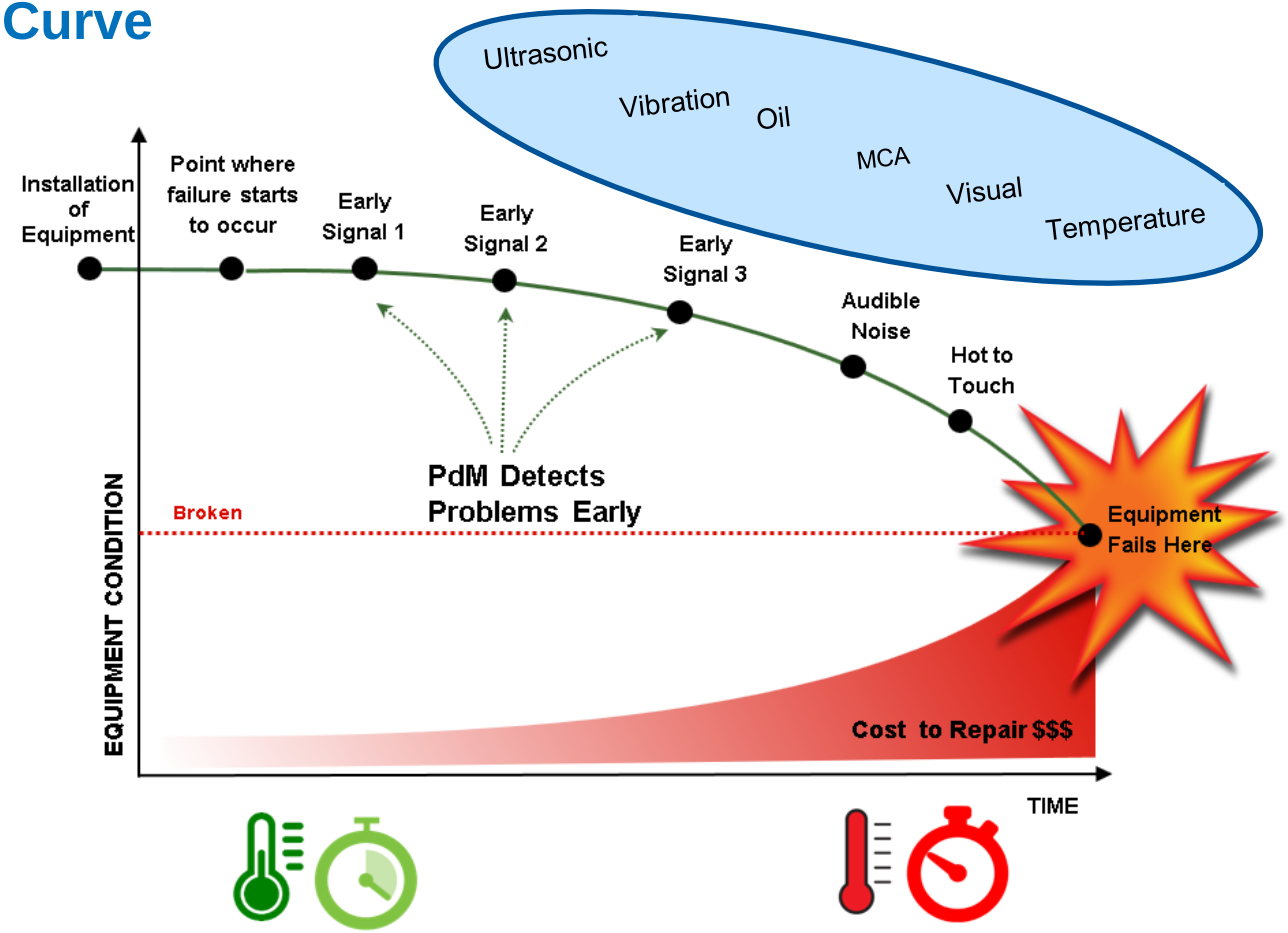
Process data vis-à-vis Machine condition data

- Process data - continuous online measurements
  - Data source - Control, Safety, Environmental, Process monitoring, Trips/Interlocks
  - SCADA, PLCs, other instrumentation, IIoT …
  - Process measurements - Pressure, temperature, flowrate, level, amperage, voltage
  - Equipment states - Open/Close, Running/Stopped,…
  - Operator rounds
  - ….
- Machine condition data - may not be on-line and may not be continuous
  - Vibration
  - Infrared (thermography)
  - Acoustic (ultrasound)
  - Oil sampling - motor oil, transformer oil…
  - Motor current analysis
  - Strain-gauge (coke drums in a refinery)
  - Machinery inspection, surveillance, operator rounds, …
  - …

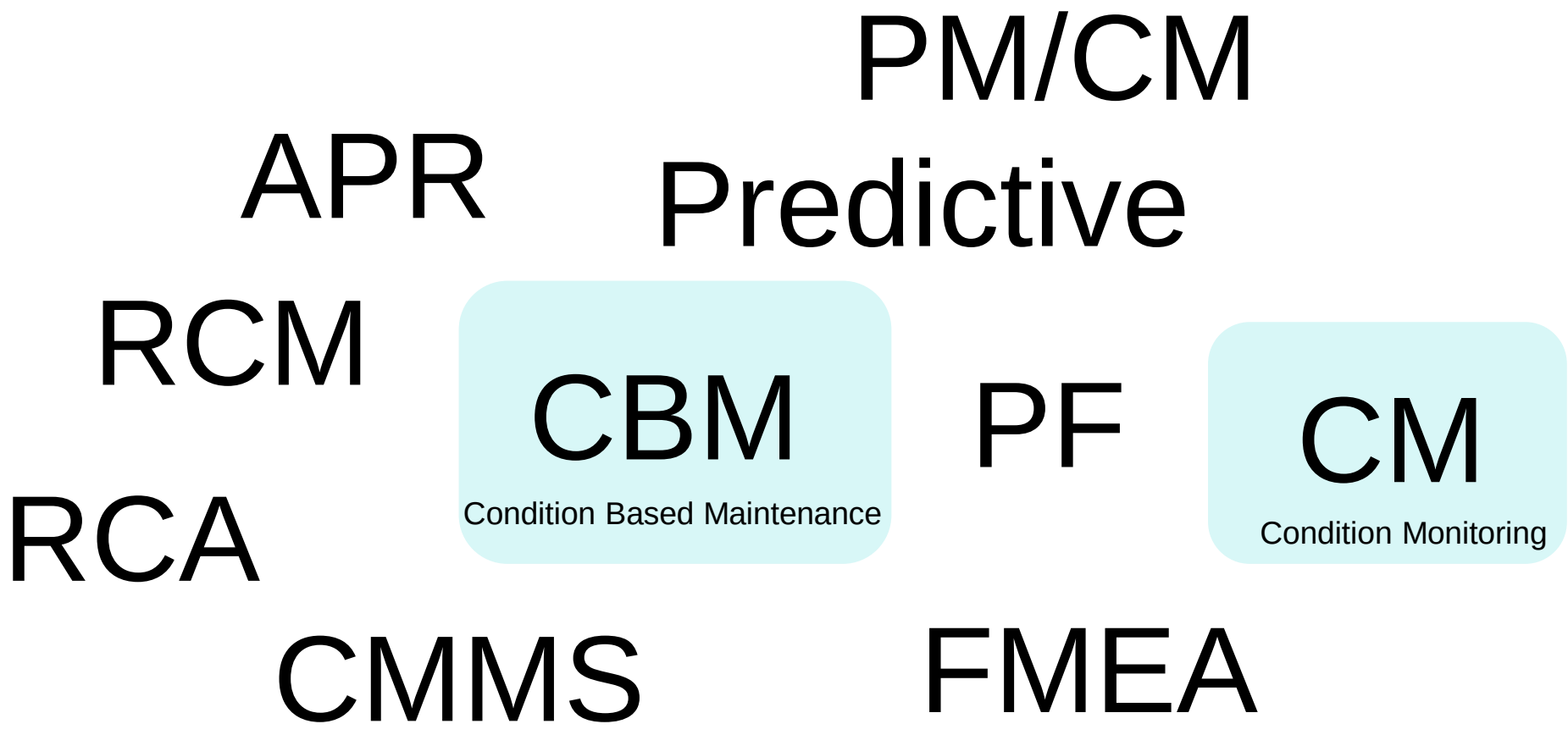
Layers of Analytics - Maintenance & Reliability



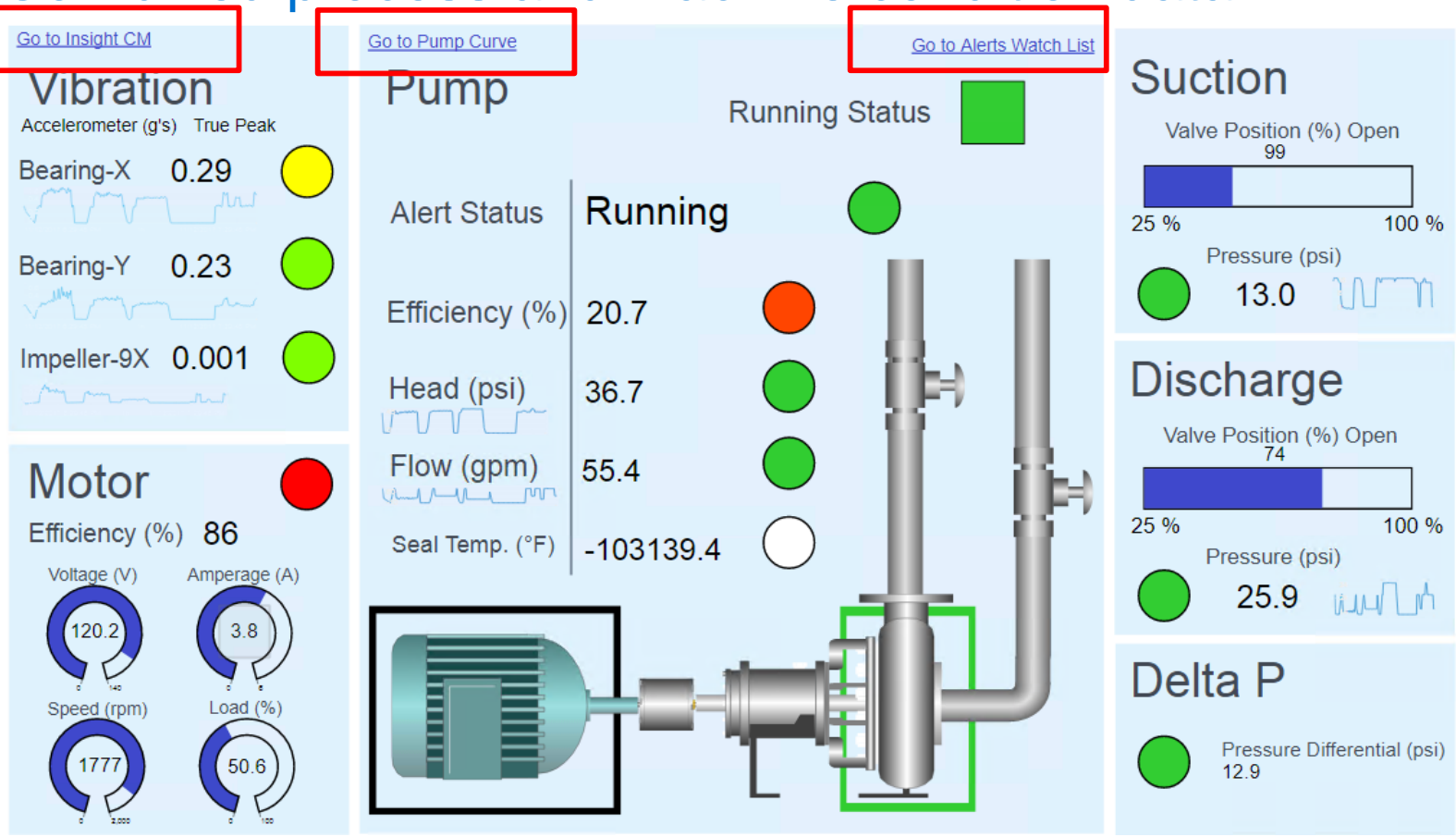
P-F Curve



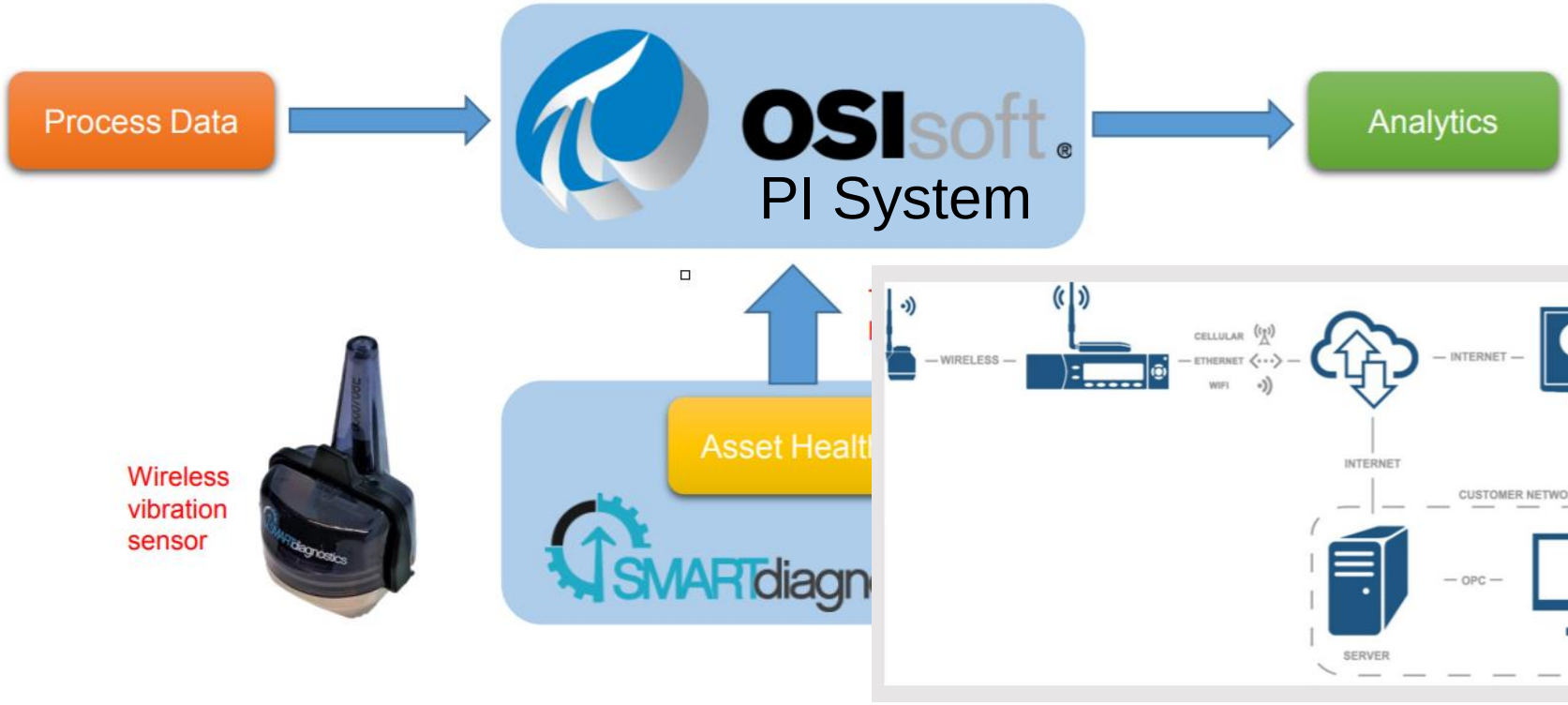
Terms & Definitions



Combined process and machine condition data

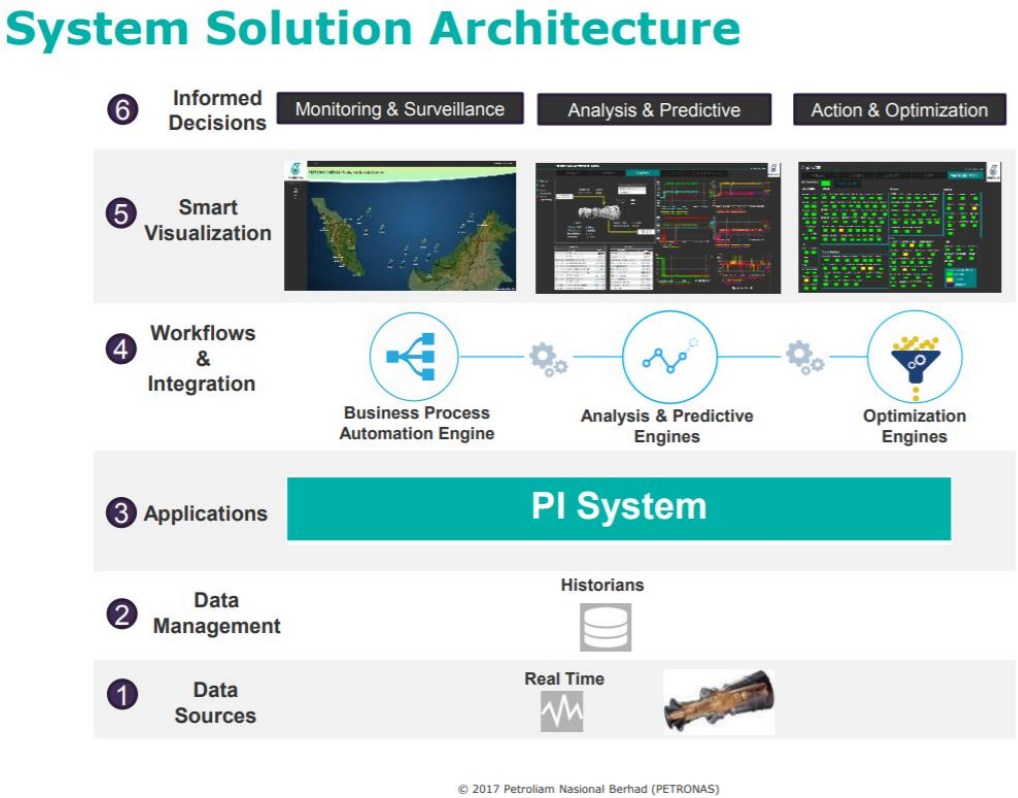


AMEREN Process data + Vibration data



https://www.osisoft.com/Presentations/Journey-to-a-new-paradigm-in-utility-condition-based-maintenance--Amerenx/

PETRONAS - Rotating Equipment Analytics



https://www.osisoft.com/Presentations/PROTEAN---Rotating-Equipment-Analytics-in-PI-AF-at-Petronas/

PETRONAS - Rotating Equipment Analytics

Initial Problem Statement

Over 130 pieces of gas turbine driven equipment

Numerous manufacturers

Cer

Ge

30+ Pieces

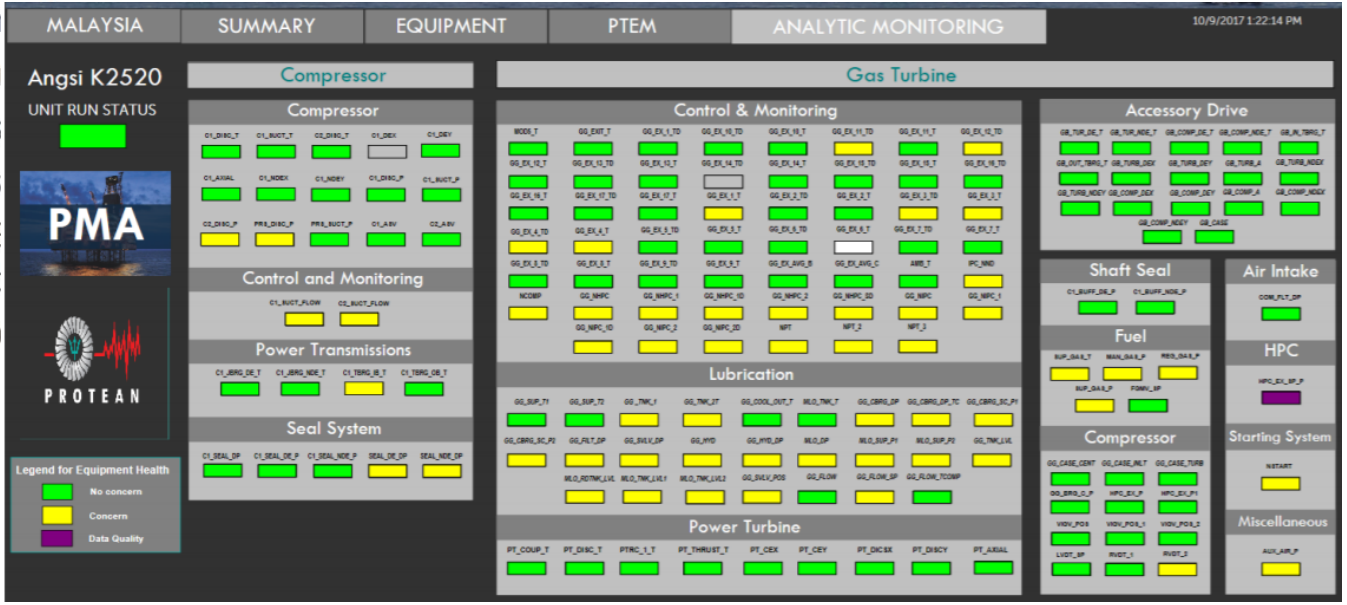
Numerous

OEM and 3

considerab

Managem

PETRONAS



https://www.osisoft.com/Presentations/PROTEAN---Rotating-Equipment-Analytics-in-PI-AF-at-Petronas/

Video – User examples

https://www.youtube.com/watch?v=yo_BAf4YBKA

Analytics - Run-hours - Usage-based maintenance

OSIsoft.

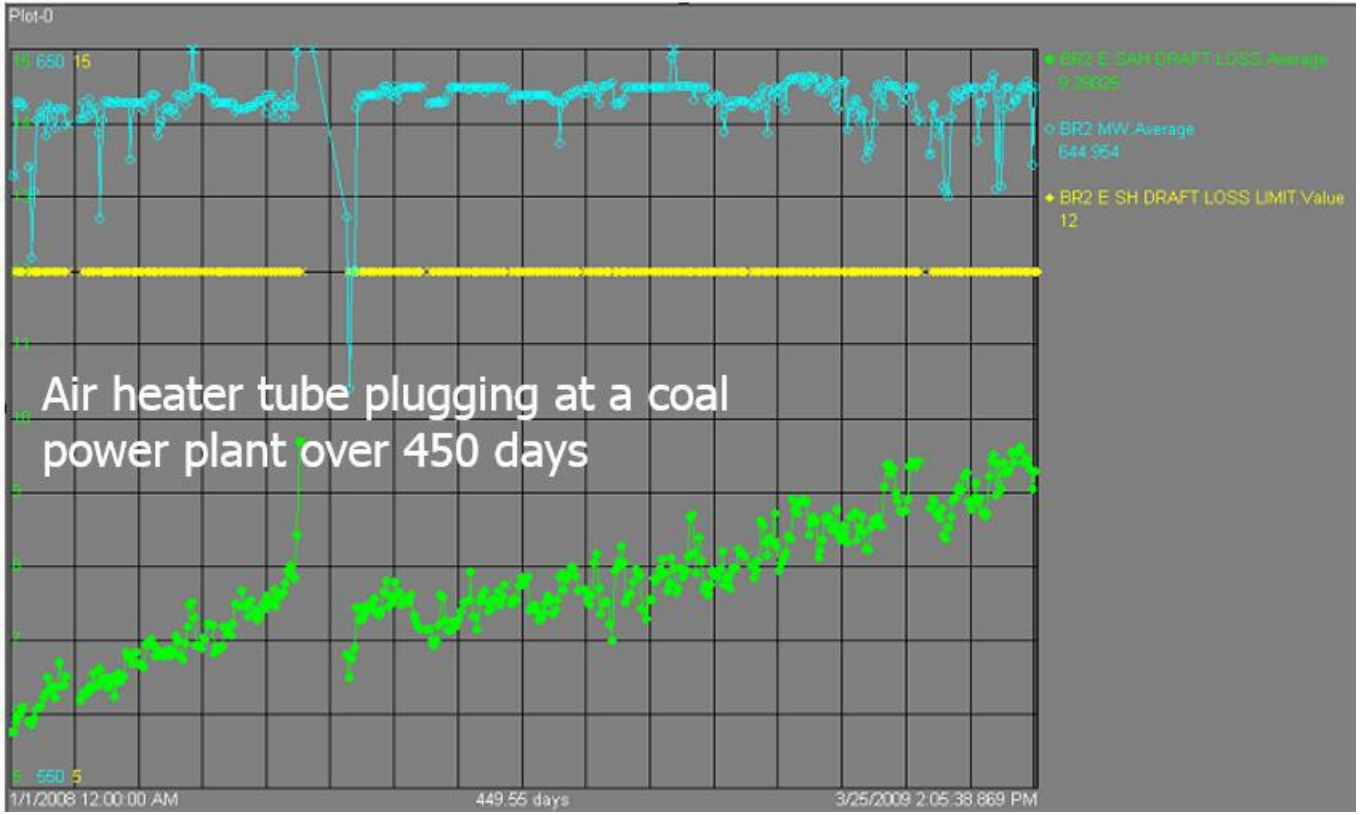
Report - Critical Motors - Run Hours

Last Update: 3-12-2016

Equipment	Daily Run Hours	Lifetime Run Hours	During Last Period	Period	Since Last Service	Last Service	Next Service
Agitator 1204	4.51	7,975	0	3mo	387	1/10/2016	11/10/2016
Agitator 1205	23.79	10,119	2,154	3mo	409	2/23/2016	10/3/2016
Agitator 1304	23.49	9,908	2,118	3mo	697	2/11/2016	12/13/2016
Agitator 1305	23.49	9,908	2,118	3mo	697	2/11/2016	12/1/2016
Fan 5163	19.71	8,554	1,174	3mo	2,664	10/1/2015	5/1/2016
Fan 5164	23.97	9,292	2,022	3mo	3,566	10/2/2015	5/2/2016
Fan 8144	14.44	9,839	2,112	3mo	3,635	10/5/2015	5/5/2016
Pump 3809	15.16	8,587	1,949	3mo	3,218	10/10/2015	5/10/2016
Pump 3810	23.97	9,618	2,079	3mo	3,837	9/23/2015	7/1/2016

https://www.osisoft.com/presentations/introduction-to-asset-monitoring-and-condition-based-maintenance-with-the-pi-system-3x/

Analytics – condition based - air heater fouling

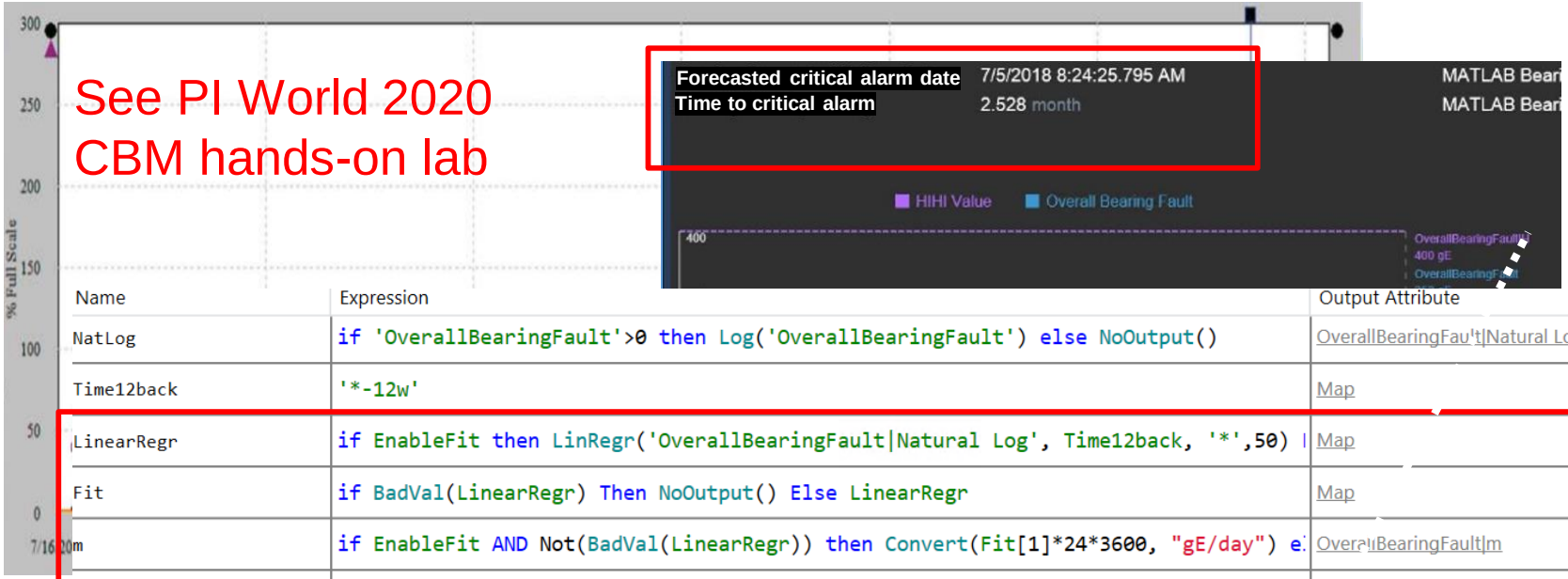


BASIN ELECTRIC POWER COOPERATIVE
A Touchstone Energy® Cooperative

https://www.osisoft.com/presentations/using-pi-to-back-test-usage-and-condition-based-maintenance-strategies-to-predict-quantifiable-benefits-prior-to-deployment-in-asset-management/

Analytics – Simple Predictive – RUL (remaining useful life)

See PI World 2020
CBM hands-on lab

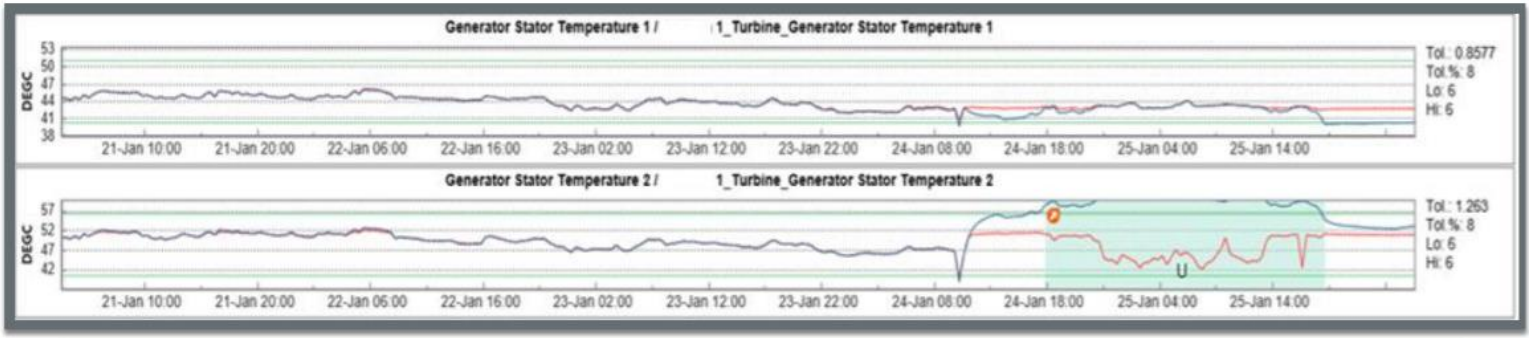


Name	Expression	Output Attribute
NatLog	`if 'OverallBearingFault'>0 then Log('OverallBearingFault') else NoOutput()`	OverallBearingFau't|Natural Log
Time12back	`'*-12w'`	Map
LinearRegr	`if EnableFit then LinRegr('OverallBearingFault|Natural Log', Time12back, '*',50)`	Map
Fit	`if BadVal(LinearRegr) Then NoOutput() Else LinearRegr`	Map
m	`if EnableFit AND Not(BadVal(LinearRegr)) then Convert(Fit[1]*24*3600, "gE/day") e`	OverallBearingFault|m
b	`if EnableFit AND Not(BadVal(LinearRegr)) then Convert(Fit[2], "gE") else NoOutput`	OverallBearingFault|b
rsquared	`if EnableFit AND Not(BadVal(LinearRegr)) then Convert(Fit[3],"ratio") else NoOutp`	OverallBearingFault|r squared
LifeExpectancy	`if EnableFit AND Not(BadVal(LinearRegr)) and m>0 and rsquared>.400 then Convert((`	BearingLifeExpectancy
ForecastedFailDate	`if EnableFit AND Not(BadVal(LinearRegr)) and m>0 and rsquared>.400 then TimeStamp`	BearingForecastedFailureDate

Analytics - advanced predictive - fault detection

ECG Predict-IT APR - Advanced Pattern Recognition

Early identification of high generator winding temperature

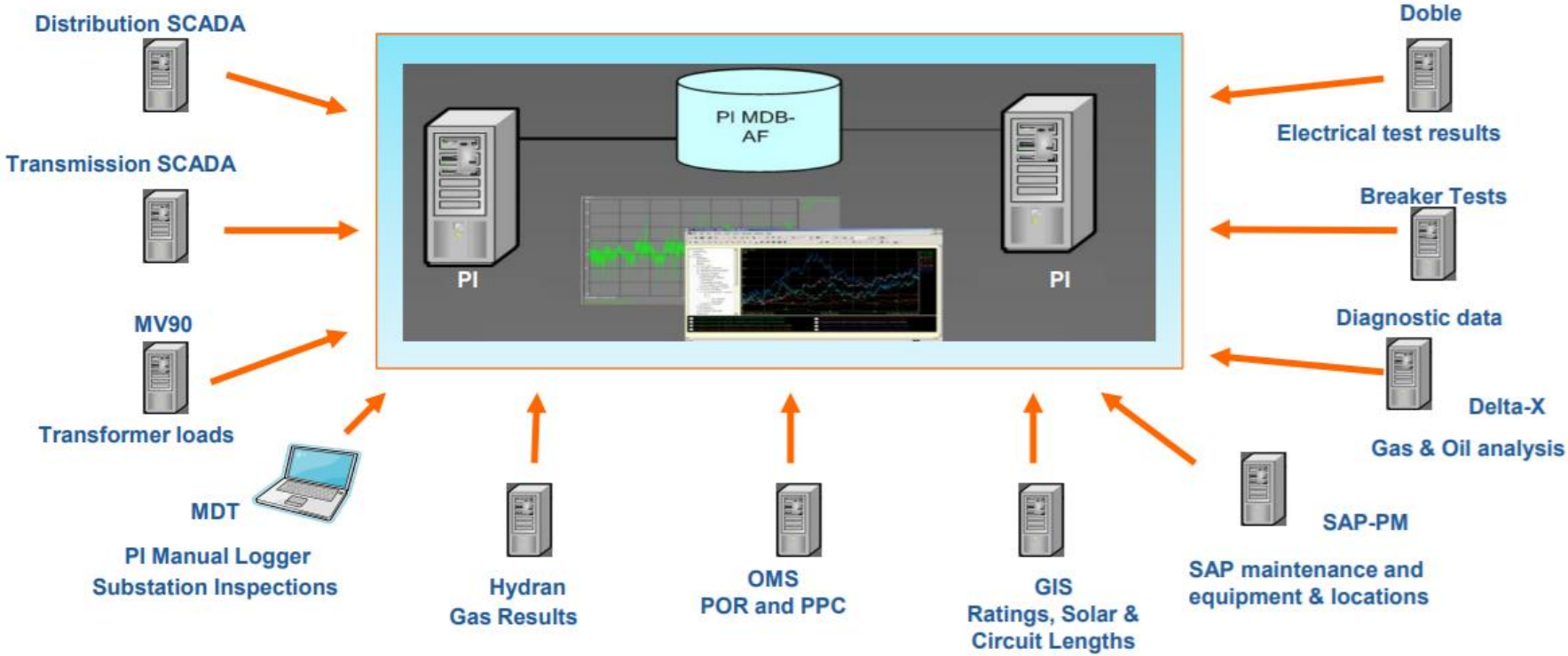


Action Taken	**Plant notification and subsequent investigation**
Corrective Action	**Hydrogen Cooler leak repaired**
Consequence Avoided	**Internal inspection and repair**

http://www.ecg-inc.com/products/predictit#video

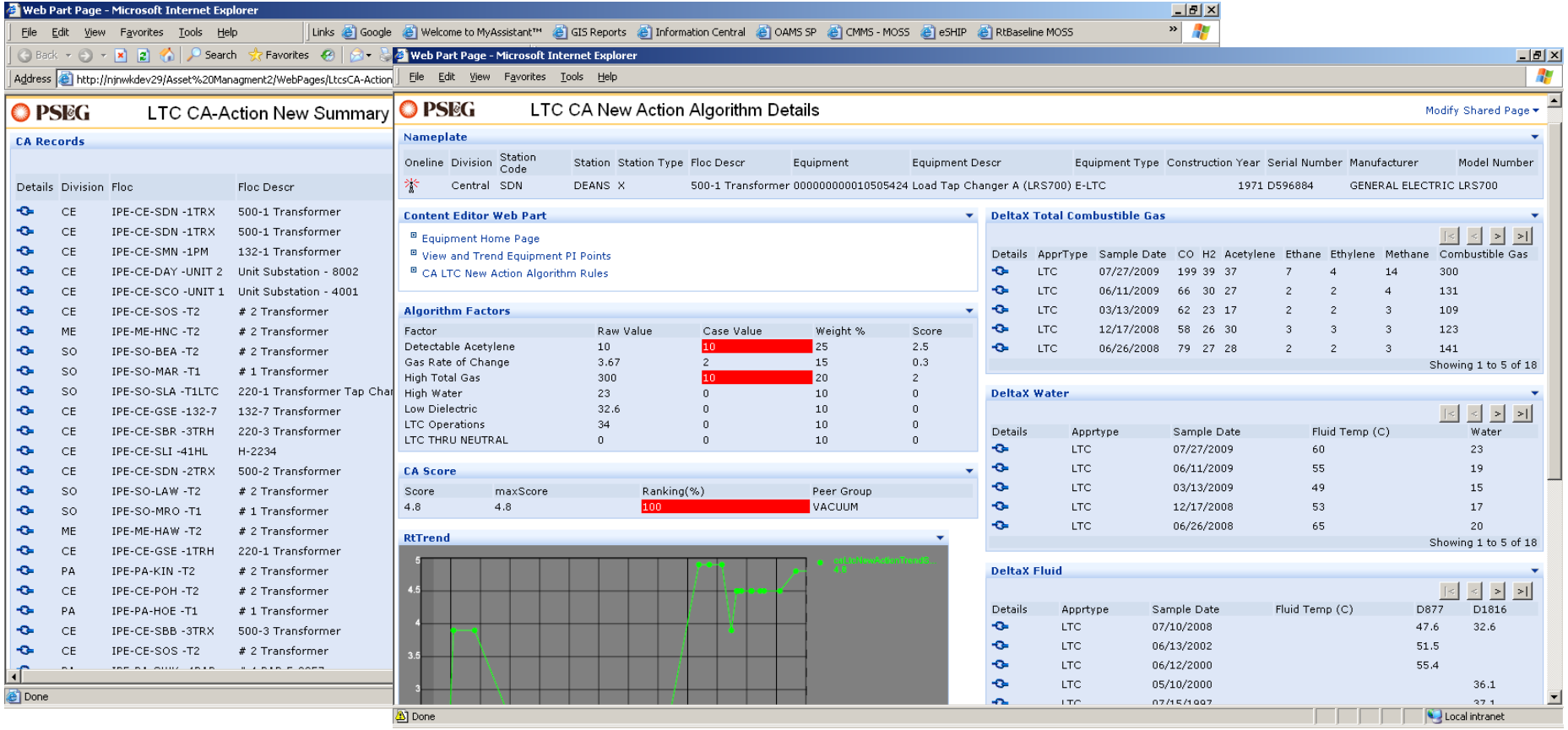
https://www.osisoft.com/Presentations/Vistra-Energy--Cloud-Transformation-in-a-Nationwide-Power-Producer/

Public Service Electric & Gas (PSE&G) – Distribution Transformers



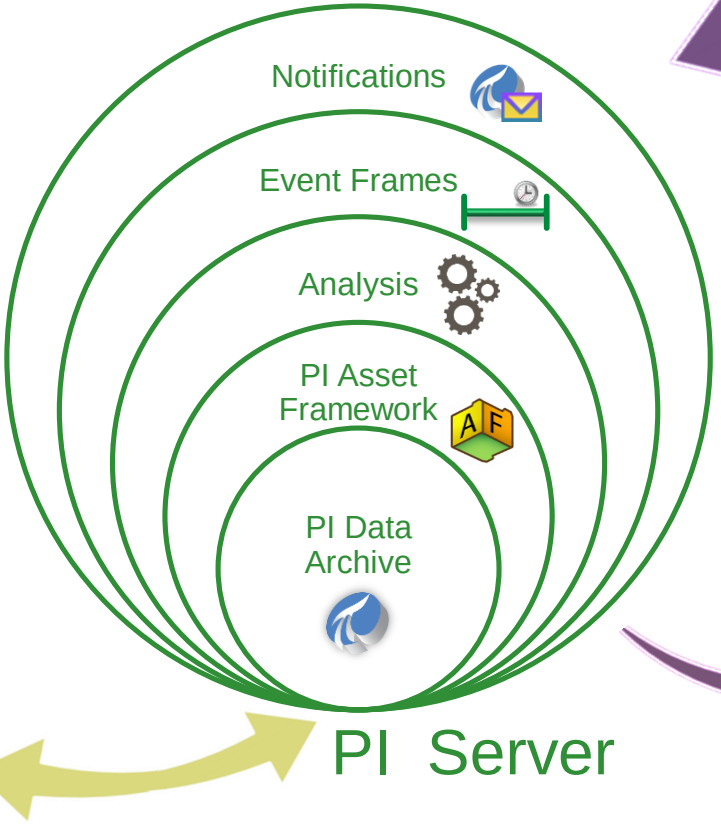
https://www.osisoft.com/Presentations/Condition-Based-Maintenance/

Watchlist with health score



https://www.osisoft.com/Presentations/Condition-Based-Maintenance/

The Modern PI System



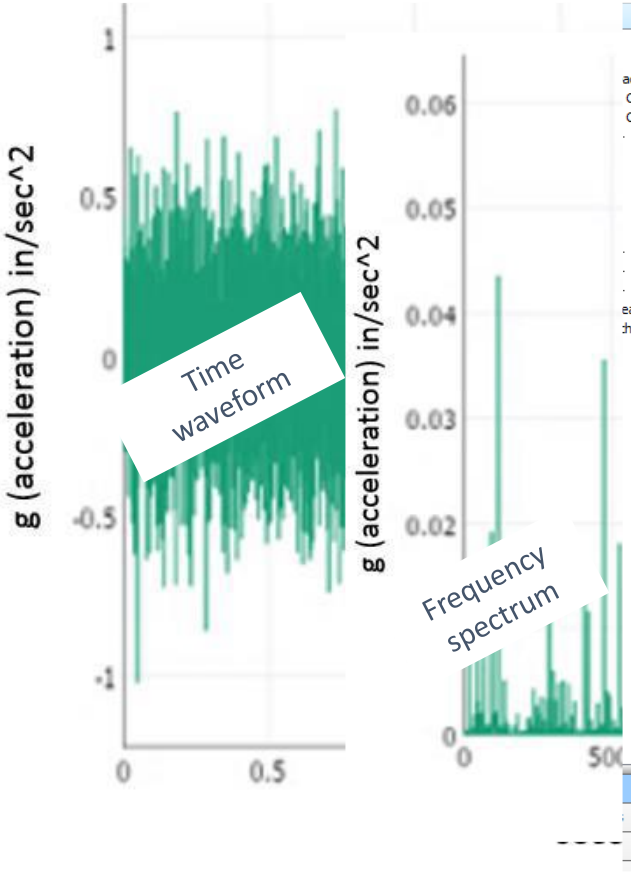
PI Integrators & PI System Access

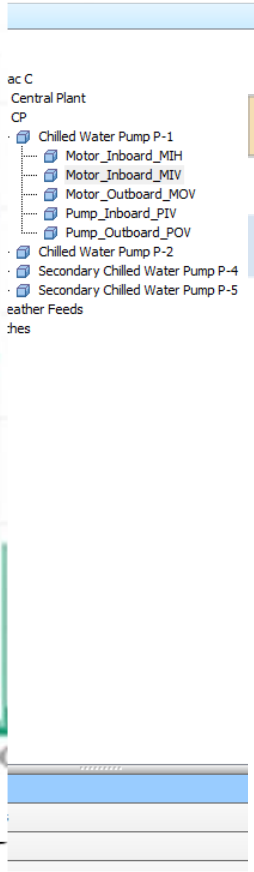
1. Connect to relevant sources
2. Collect and archive data
3. Assign context (asset-based)
4. Add Analytics logic
5. Alert and notify
6. Visualize

PI Visualization Suite

- PI Vision
- PI ProcessBook
- PI DataLink

Vibration (extracted features) data





Motor_Inboard_MIV

General | Child Elements | Attributes | Ports | Analyses | Version

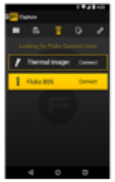
Filter

Category: Vibration data

Asynchronous	0.3679557 g (vib)
Crest Factor	3.040749 g/g (vib)
Derived Peak	0.5442402 g (vib)
High Frequency	0.1448086 g (vib)
Peak-Peak	2.268219 g (vib)
RMS	0.384836 g (vib)
Single Integrated_1x Magnitude	0.03433325 ips
Single Integrated_2x Magnitude	0.007174384 ips
Single Integrated_Derived Peak	0.0651958 ips
Single Integrated_True Peak	0.1517071 ips
Synchronous	0.09153856 g (vib)
True Peak	1.170189 g (vib)

Thermography - Infrared

Ad hoc Wi-Fi



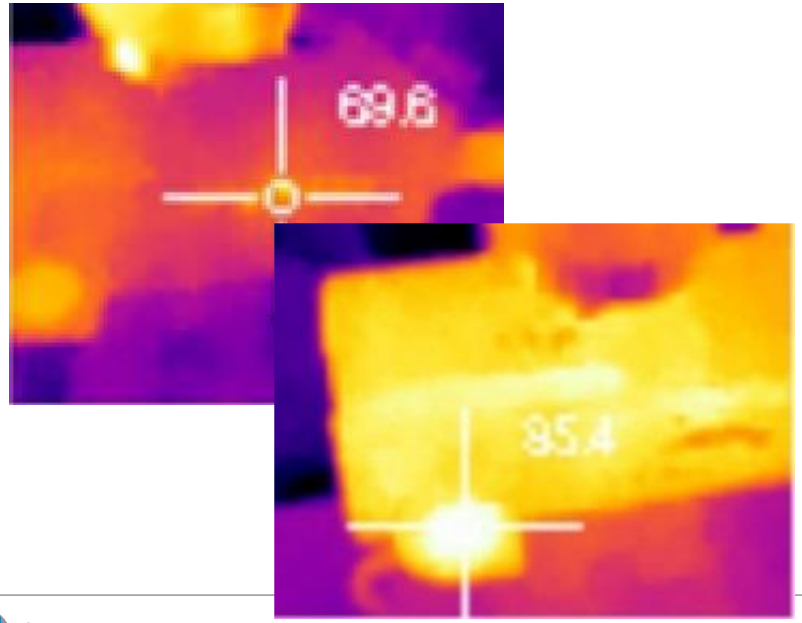
Fluke Connect

On-prem/Cloud

Windows Azure

PI System
PI Connector for UFL

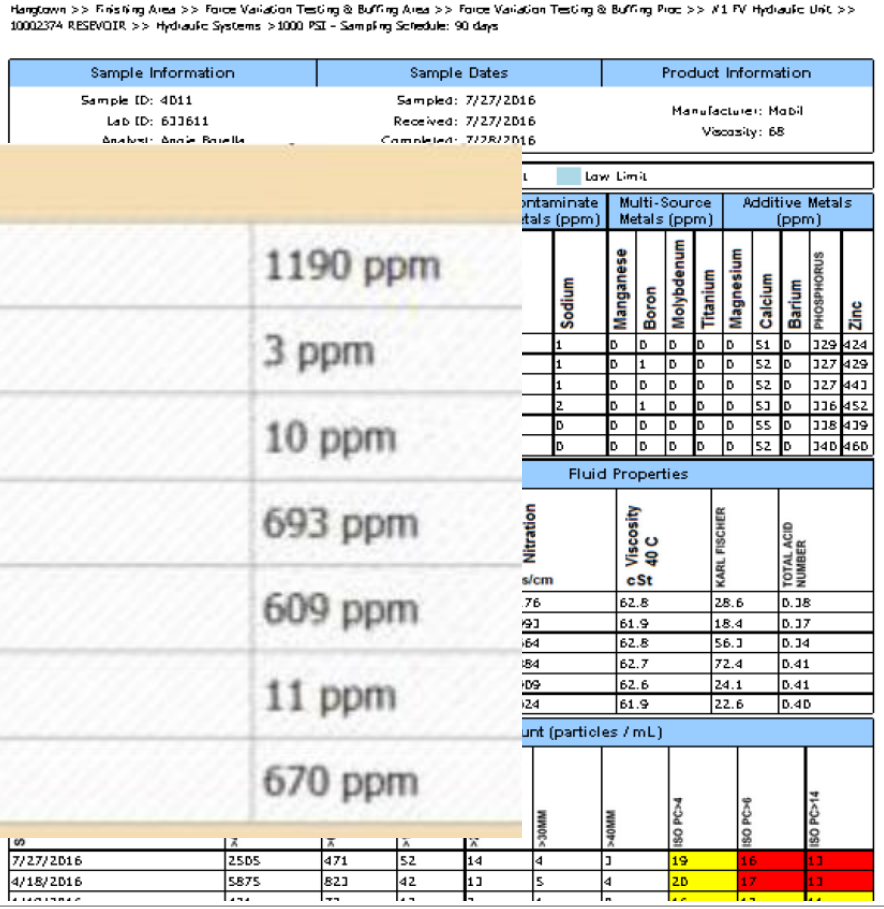
Notification Rules | Version



Name	Value	Time Stamp
Category: datasource		
Device	AR-C10	1/1/1970 12:00:00 AM
Equipment	Pump1	1/1/1970 12:00:00 AM
Category: Infrared		
Temperature	84.35568 deg F	3/19/2017 7:33:03 PM
Category: Ultrasound		
Ultrasound	20 dB	3/19/2017 7:34:51 PM
Category: Vibration		
1X	0.085273 ips	3/19/2017 7:32:46 PM
2X	0.017923 ips	3/19/2017 7:32:46 PM
rpm	800	3/19/2017 7:33:03 PM
TRUE_PEAK	0.177541 ips	3/19/2017 7:32:46 PM
V_IPS_PEAK	0.229913 ips	3/19/2017 7:32:46 PM

Oil analysis results

Category: Oil Analysis	
Calcium	1190 ppm
Copper	3 ppm
Iron	10 ppm
Magnesium	693 ppm
Phosphorus	609 ppm
Sodium	11 ppm
Zinc	670 ppm


Hangtown >> Finishing Area >> Force Variation Testing & Buffing Area >> Force Variation Testing & Buffing Proc >> #1 FV Hydraulic Unit >> 10002374 RESEVOIR >> Hydraulic Systems >1000 PSI - Sampling Schedule: 90 days

Sample Information	Sample Dates	Product Information
Sample ID: 4D11	Sampled: 7/27/2016	Manufacturer: Mobil
Lab ID: 6JJ611	Received: 7/27/2016	Viscosity: 68
Analyst: Angie Bouelle	Completed: 7/28/2016	

Low Limit

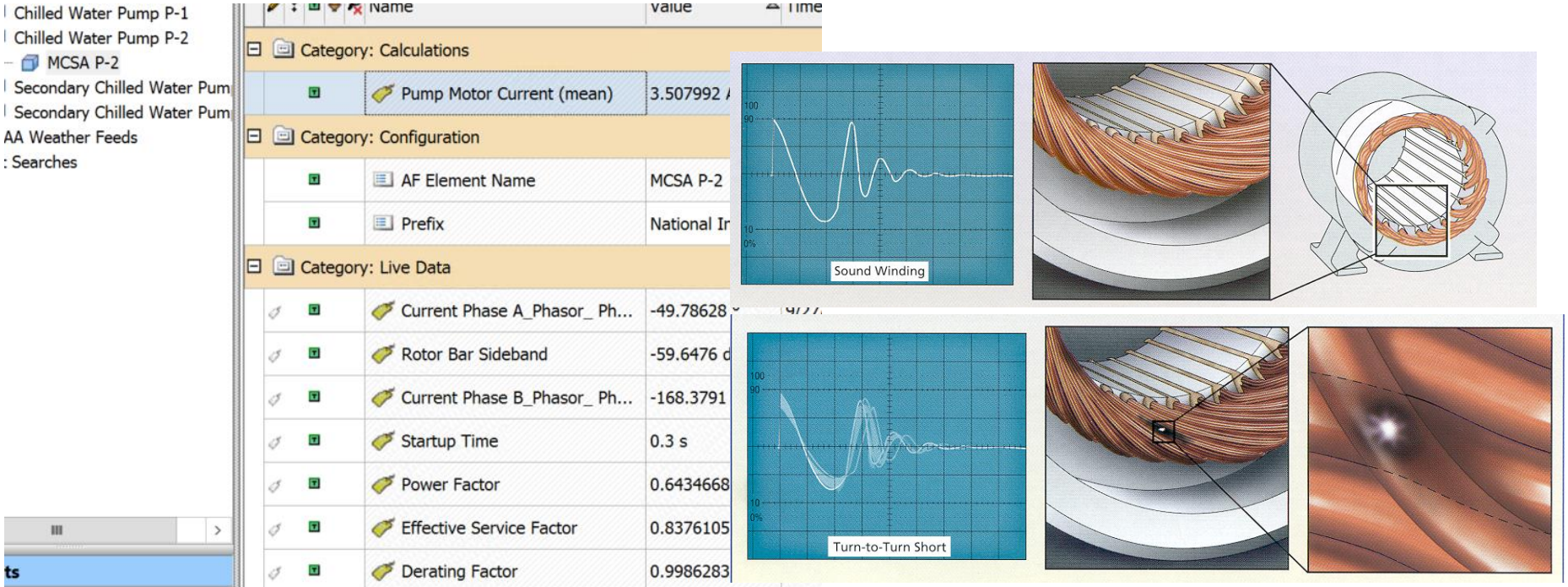
Contaminate Metals (ppm)	Multi-Source Metals (ppm)			Additive Metals (ppm)				
Sodium	Manganese	Boron	Molybdenum	Titanium	Magnesium	Calcium	Barium	PHOSPHORUS	Zinc
1	0	0	0	0	0	51	0	329	424
1	0	1	0	0	0	52	0	327	429
1	0	0	0	0	0	52	0	327	441
2	0	1	0	0	0	51	0	316	452
0	0	0	0	0	0	55	0	318	439
0	0	0	0	0	0	52	0	340	460

Fluid Properties			
Nitration s/cm	Viscosity 40 C cSt	KARL FISCHER	TOTAL ACID NUMBER
76	62.8	28.6	0.38
93	61.9	18.4	0.37
64	62.8	56.3	0.34
84	62.7	72.4	0.41
09	62.6	24.1	0.41
24	61.9	22.6	0.40

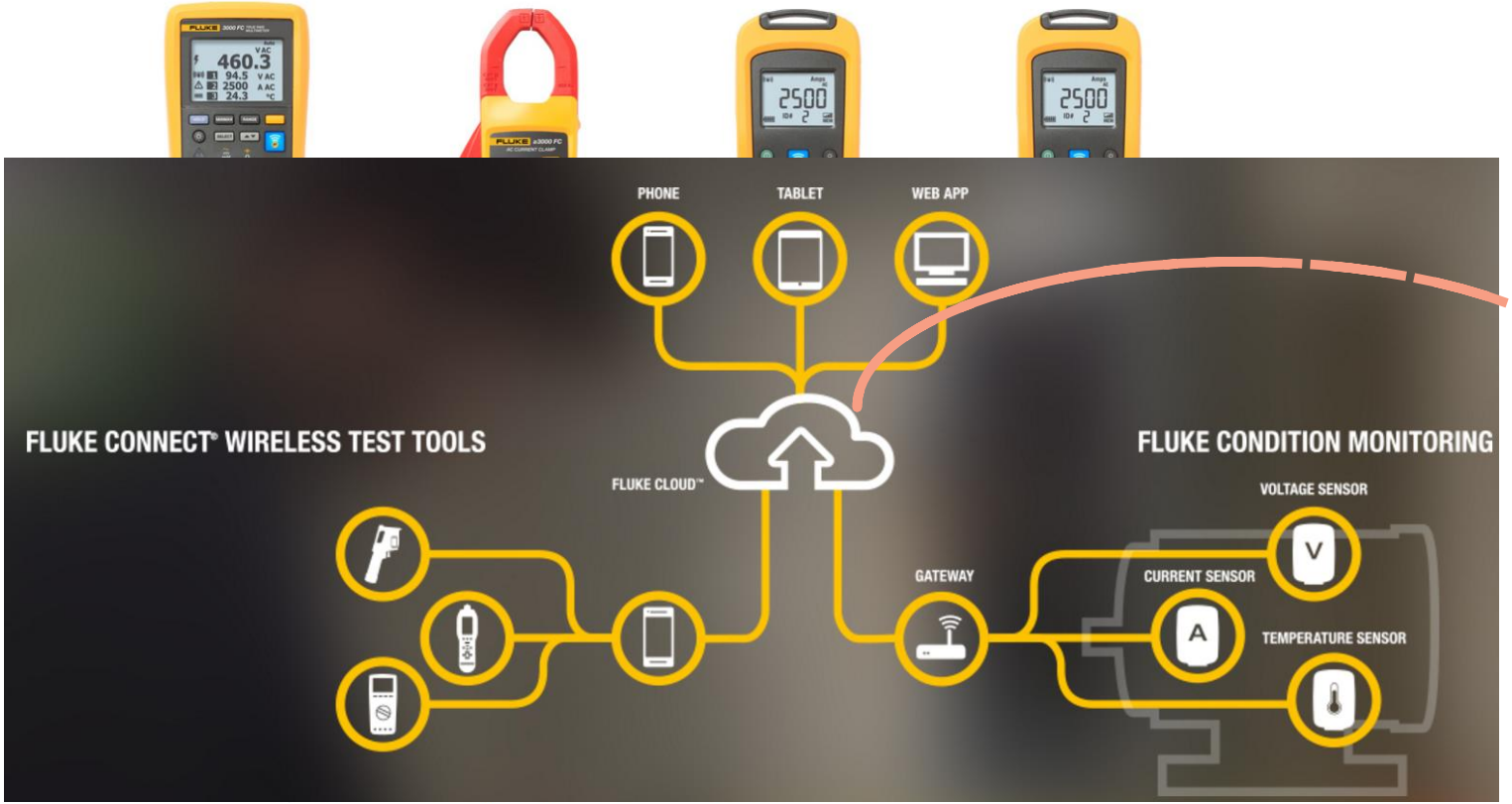
unt (particles / mL)				
>30MM	>40MM	ISO PC>4	ISO PC>6	ISO PC>14
4	3	19	16	13
5	4	20	17	13

99	X	X	X	X
7/27/2016	2505	471	52	14
4/18/2016	5875	823	42	13

Electric Motor Current Analysis



Fluke Connect Modules:

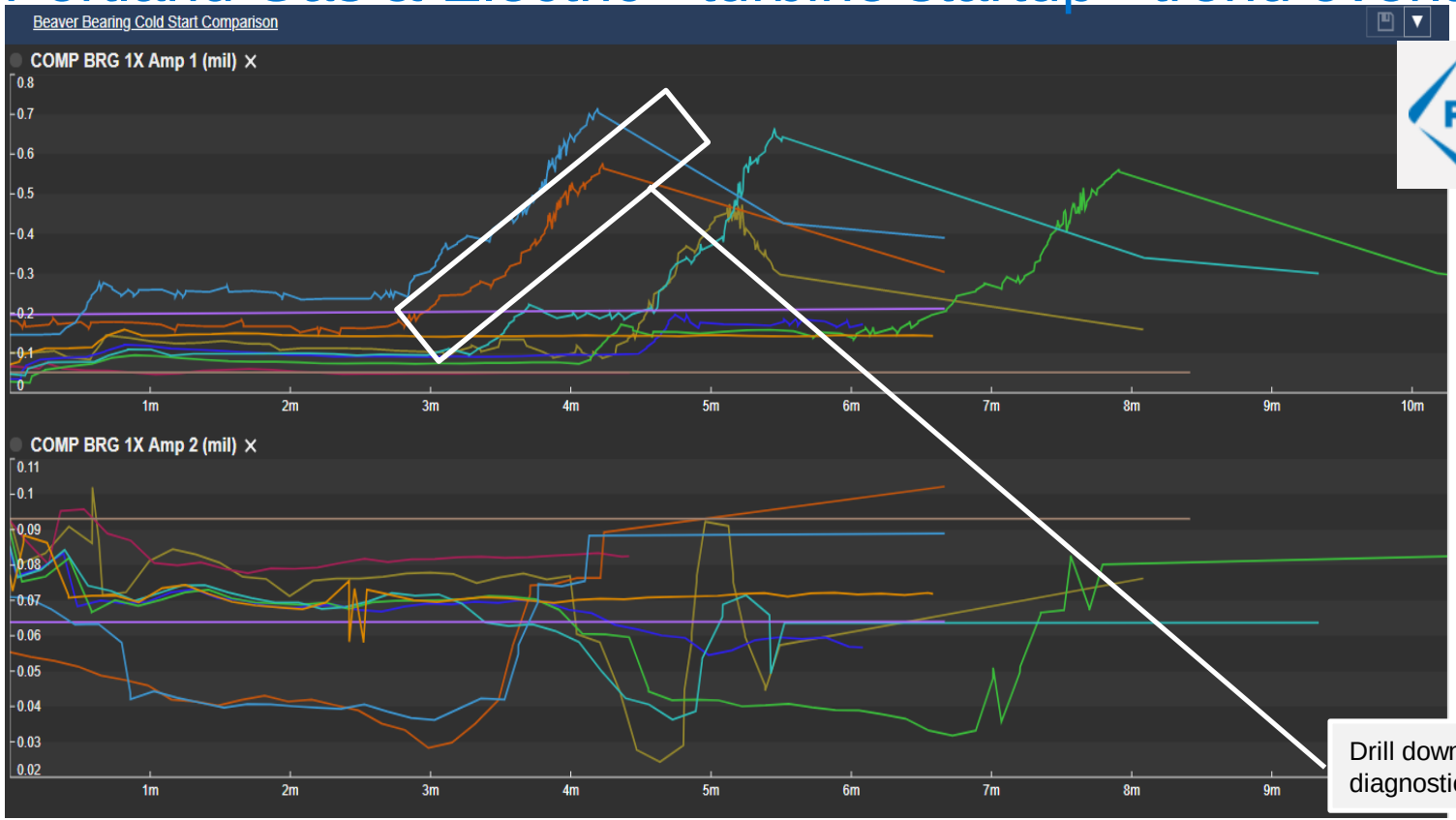


PI UFL Connector http Listener

PI System

https://www.myflukestore.com/content/fluke_connect

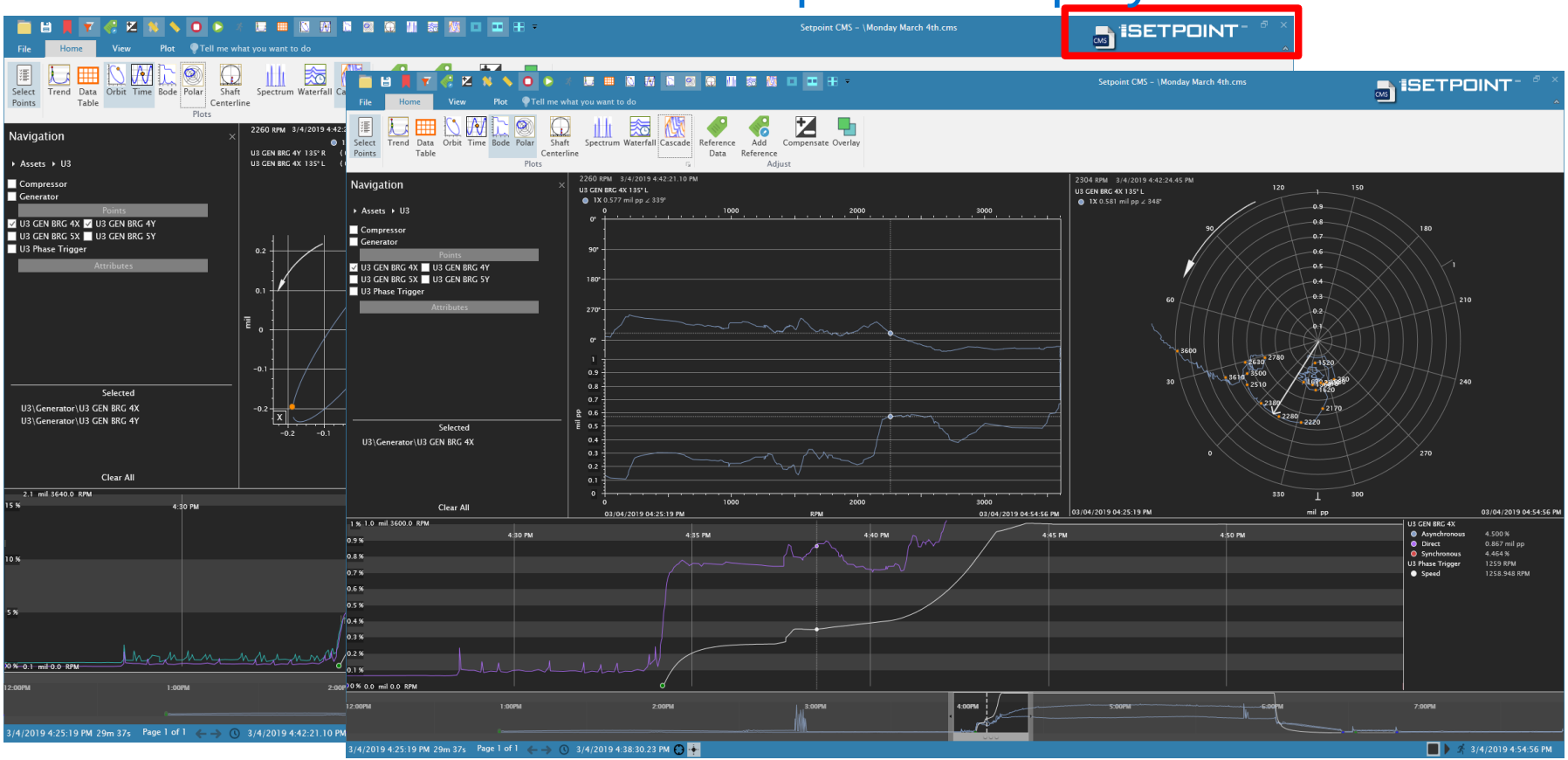
Portland Gas & Electric - turbine startup - trend overlays



Drill down to detailed vibration diagnostics display

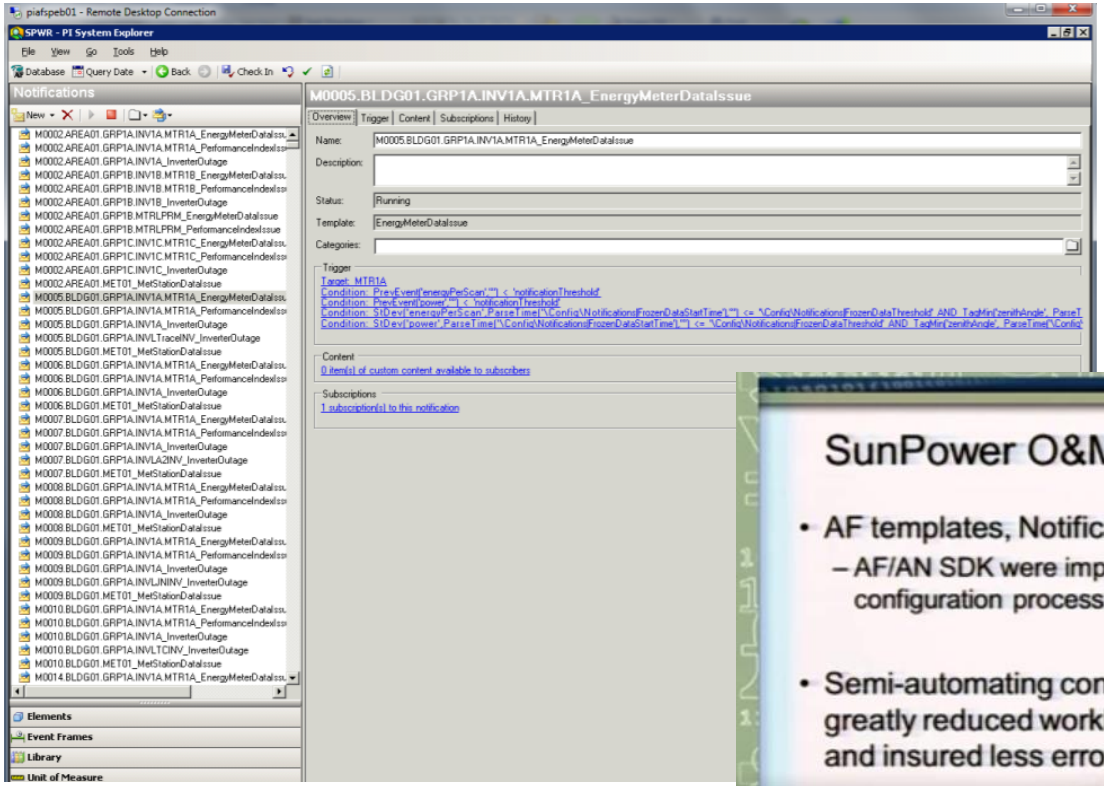
https://www.osisoft.com/Presentations/Experience-using-the-PI-System-for-Full-Featured-Vibration-Monitoring-at-Portland-General-Electric/

Vibration – time waveform and spectral displays

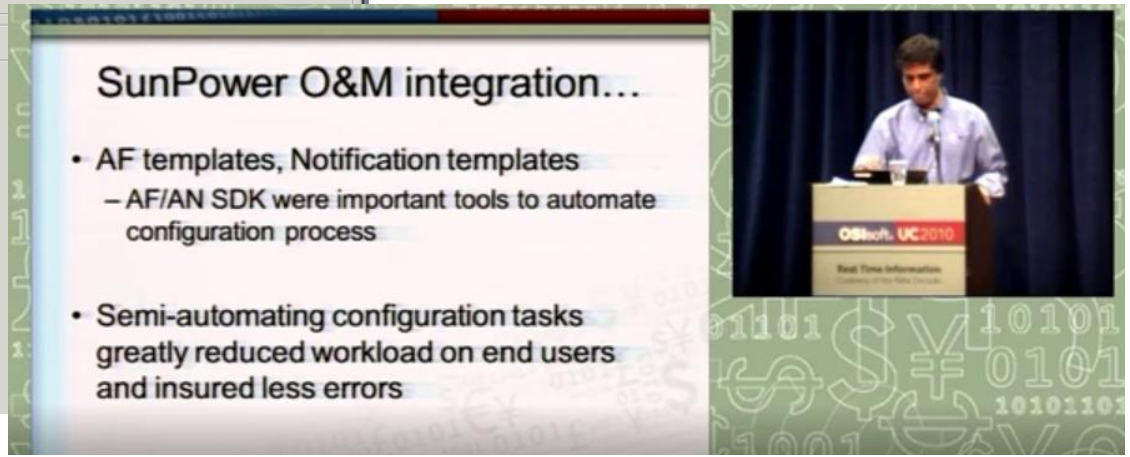


https://www.osisoft.com/Presentations/Experience-using-the-PI-System-for-Full-Featured-Vibration-Monitoring-at-Portland-General-Electric/

PI data model – Renewables – Solar, Wind…



SUNPOWER®



https://www.osisoft.com/presentations/af-implementation-in-enterprise-asset-management/

Takeaways – layered analytics - usage-based, condition-based and predictive maintenance

- Combined machine condition & process data
  - vibration, thermography, oil analysis, ….
  - pressure, flow, voltage, amperage…

- Layered Analytics
  - Usage assessment - run-hours
    - fan run-hours, pulverizer tonnage, motor starts/stops, …

  - Condition assessment - machine and/or process
    - low motor efficiency, high vibration, high filter DP, fouled heat-exchanger…

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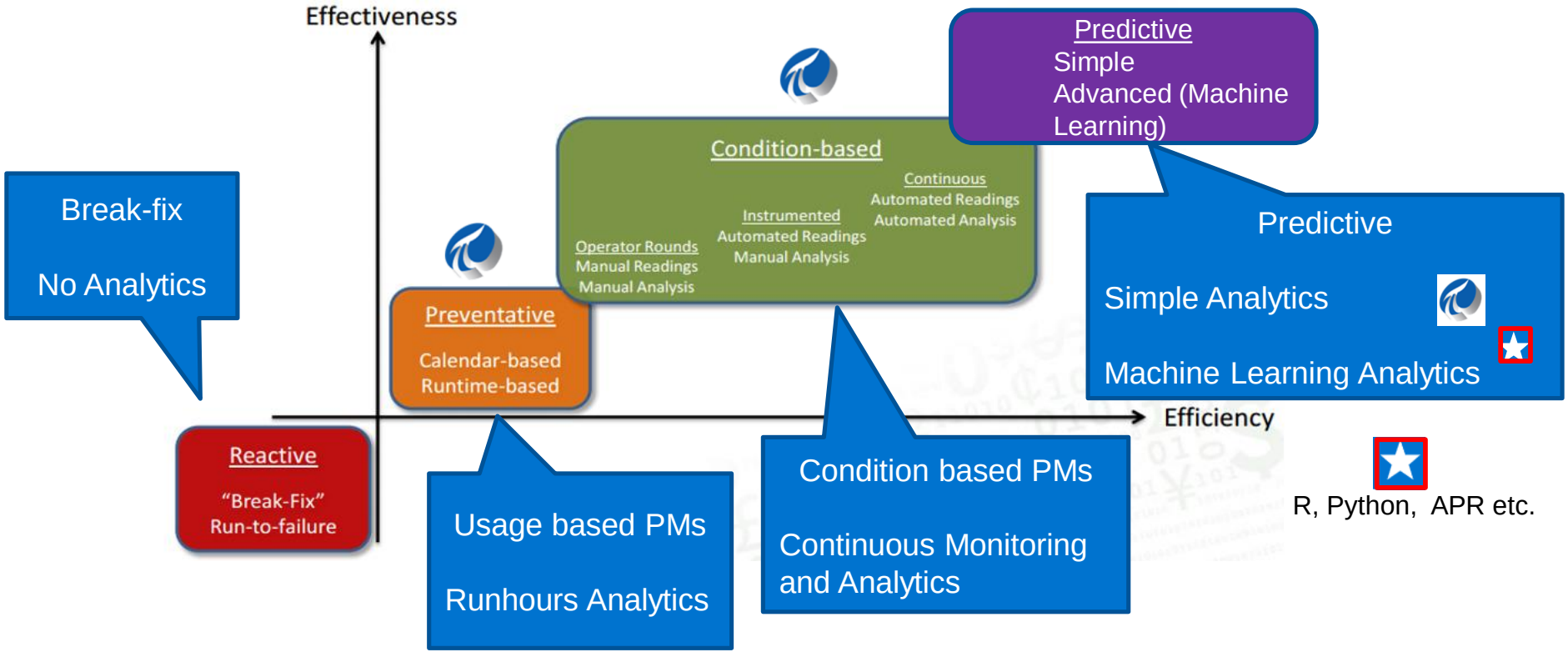
  - Predictive - Advanced – machine learning, APR etc. – anomaly detection, early failure warning…
  - Asset Health Score - combined and weighted scores of many condition indicators
    - distribution transformer - LTC (load tap changer) count, DGA (dissolved gas), nitrogen pressure, …

Layers of Analytics - Maintenance & Reliability



Customer deployments

Portland General Electric - power generation Experience-using-the-PI-System-for-Full-Featured-Vibration-Monitoring
NTPC – power generation PI System - a Journey
NTPC - power generation Deviation Settlement Mechanism (DSM) - Availability Based Tariff (ABT) application
Ultratech – Power and Cement -Health Monitoring of Power Plants: Pan India
Ameren - nuclear power generation A-new-paradigm-in-utility-condition-based-maintenance
Vistra Energy (Luminant) - power Cloud-Transformation-in-a-Nationwide-Power-Producer
Barrick Gold - metals & mining Mine-Haul-Truck-Health-Monitoring-System
EQT - natural gas pipeline Reliability-Centered-Maintenance-Program
King County - waste water treatment PI-as-a-Maintenance-Tool
PSE&G - electricity distribution - transformers Condition-Based-Maintenance-Case-Study
PSE&G - electricity distribution - circuits Extending-Condition-Based-Maintenance-Program-to-Underground-Networks/
Petronas - oil & gas PROTEAN---Rotating-Equipment-Analytics-in-PI-AF
Silicon Valley Power - power generation Optimizing-Predictive-Maintenance-by-Integrating-Vibration-Data-and-Process-Data
SNCF - railways Using-Operational-Data-for-the-Future-Maintenance-of-the-French-Rail-Infrastructure
Alyeska Pipeline - oil & gas Achieving-Reliability-Centered-Maintenance-and-Diagnostics-with-the-PI-System
ADNOC - oil & gas Improving-Equipment-Reliability-and-Availability-through-Real-time-Data
Las Vegas Valley Water District - water treatment Evaluating-Efficiency-and-Predicting-Maintenance-with-Existing-Data-Using-PI-AF-and-Asset-Analytics
Chevron – oil exploration Condition-Based-Maintenance-and-Smart-Monitoring-in-Frade-FPSO-with-the-PI-System
Vattenfall – hydro power Deploying-a-Condition-Based-Maintenance-Strategy-in-the-Hydro-Power-Business
PowerStream - electricity distribution Equipment-Failure-is-Not-an-Option
GenOn Energy - power Proactive-Maintenance-Data-Gateway-Built-on-the-OSIsoft-PI-System-Infrastructure
Uniper - power How-OSIsoft-PI-supports-Unipers-Maintenance-Strategy-Planning
ESB - power Using-the-PI-System-in-Power-Generation-Operation-and-Maintenance-to-Optimise-Commercial—Environment
MOL – oil refinery Supporting-Operational-Availability-by-Connecting-the-PI-System-and-SAP-PM
OSIsoft Introduction-to-Asset-Monitoring-and-Condition-based-Maintenance-with-the-PI-System
OSIsoft Getting-started-with-iiot-sensors (may need to register – free)
OSIsoft PI System components in CBM – How to
OSIsoft What is the PI System for a Maintenance Engineer?

Thank You

Next Steps:

>Your Digital Transformation use case

>PI Workshop

>https://learning.osisoft.com

>https://pisquare.osisoft.com/ (Community and Developer)