

Asset Monitoring and Condition-based Maintenance (CBM) with the PI System

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Agenda

- CBM Overview
- PI System and the CBM process
- CBM Resources

Terms & Definitions

PM/CM

APR

Predictive APM

RCM

CBM

Condition Based Maintenance

PF

CM

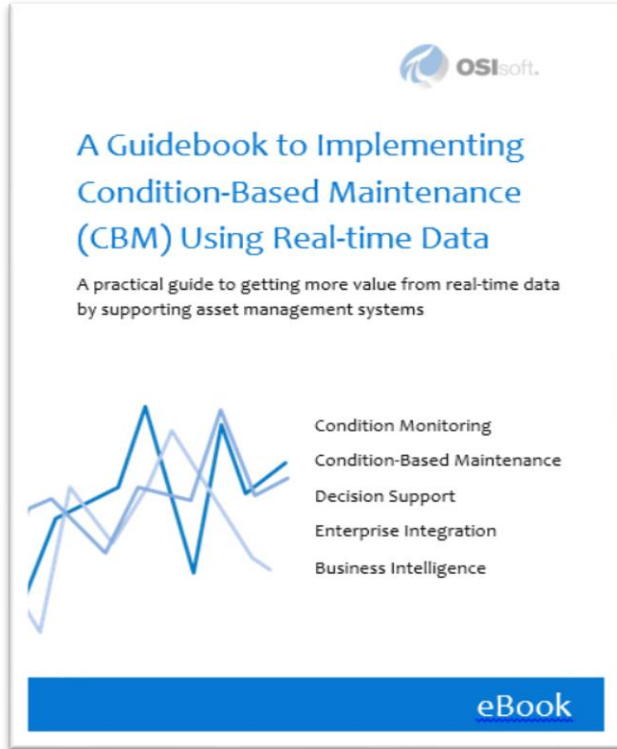
Condition Monitoring

RCA

CMMS

FMEA

CBM Prescriptive Guidance



Terms & Definitions

Implementation Guidance

PI System Overview for CBM

PI System Integration w/ CMMS

Enabling Opportunities

Solution Examples

Industry References

Maintenance Budget & Types

- Capital replacement
 - Replace or rebuild expensive assets
 - Major projects
 - Squeaky wheel gets the grease syndrome
- Corrective Maintenance (CM)
 - Repair a failure or degradation
 - Troubleshoot & Rework
 - Unscheduled often with downtime
- Preventive Maintenance (PM)
 - Usually time-based schedules
 - Clean & Inspect
 - Pack bearings
 - Filter check
 - Diagnostic Measurements & tests

Capital \$

Asset
Management

O&M \$

Maintenance &
Engineering

**Capital
Replacement**

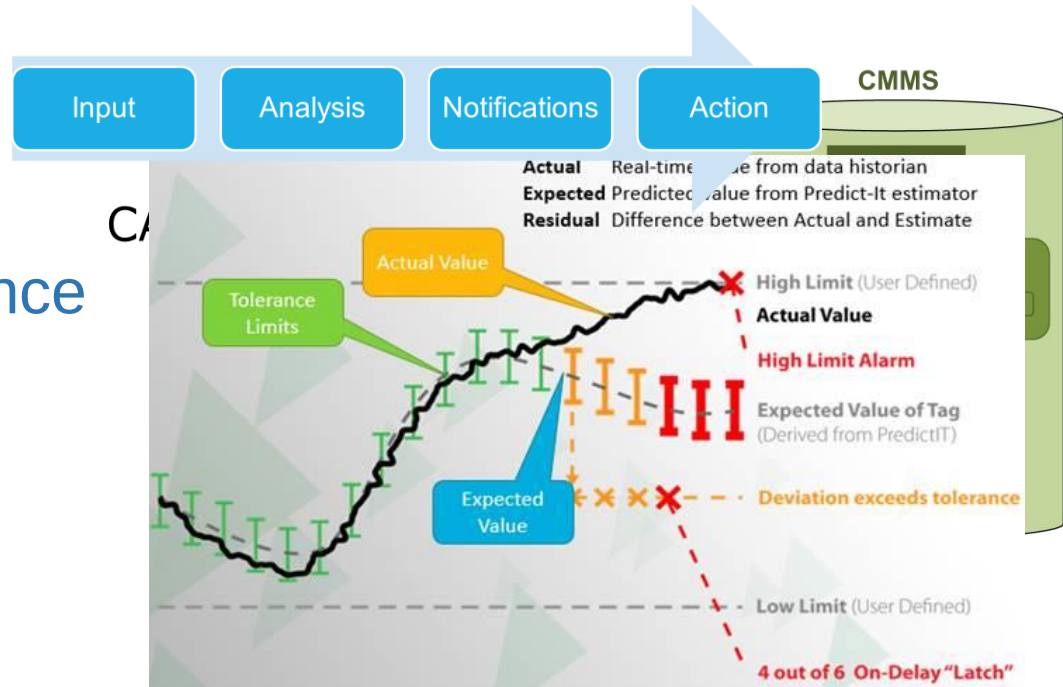
**Corrective
Maintenance**

**Preventive
Maintenance**

- More targeted expenditures
- More planned, less disruptive
- Fewer PM's
- Some Corrective / Planned

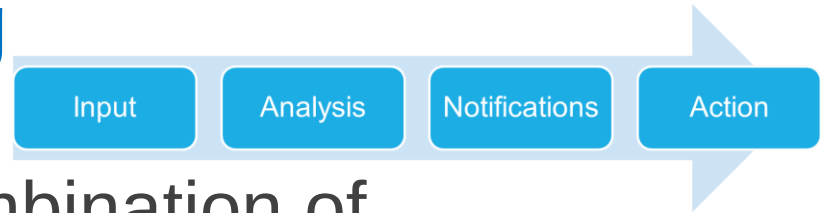
CBM can mean different things

- Condition Monitoring
- Condition Assessment
- CBM Preventive Maintenance
- APR – Advanced Pattern Recognition



It's a journey – not a destination

#1 Condition Monitoring



- May be any single or combination of performance indicators
 - Vibration (with operational data)
 - Efficiency (and degradation over time)
 - Temperature (compared to usage and ambient conditions)
 - May be simple or complex
 - Incidence over time may be critical

Calculating Expected Heat Rate

_CoeffType	ECMax
A	3.01916
B	0
C	-140.82336
D	0
E	3431.05804
F	0
G	-39811.23565
H	0
I	226037.87046
J	0
K	-524290.83316
L	0
M	0
N	0
O	0
P	0
Q	0

Lookup curve-fit coefficients from SQL Table
(Manufacturer Performance Curves)

Data Reference: Table Lookup

Settings...

```
SELECT CoefficientValue FROM PerformanceCentrEff WHERE PerformanceModelID = @[PerformanceModelID] AND CoefficientType = @[CoefType] AND CoefficientOrder = 1
```

Real-time Streaming Analytics

$$Q = \frac{\Delta P_{DD} * kh}{141.2 \mu B_0 \left\{ \ln \frac{r_e}{r_w} - \frac{3}{4} + S \right\}}$$

Apply curve-fit to calculate Nominal Heat Rate

Data Reference: Formula

Settings...

```
S=...Driver [Steady Speed;A=,|A;B=,|B;C=,|C;D=,|D;E=,|E;F=,|F;G=,|G;H=,|H;I=,|I;J=,|J;K=,|K;L=,|L;M=,|M;N=,|N;O=,|O;P=,|P;Q=,|Q;X=FC_MaxSpeed;[if not(S) then 0 else (A + C*X^2 + G*X^3 + I*X^4 + K*X^5 + M*X^6 + O*X^7 + Q*X^8)/(1 + B*X + D*X^2 + F*X^3 + H*X^4 + J*X^5 + L*X^6 + N*X^7 + P*X^8)]
```

Category: Nominal Values		
BHP_Nominal	8710.27322604474	BHP
FuelRate_Nominal	71.1036975854648	MCFH
HeatRate_Nominal	8163.19944739005	BTU(LHV)/BHP-hr
PCD_Nominal	205.15303353481	psi
T5_Nominal	1394.59524035539	°F
T7_Nominal	925.386891989674	°F

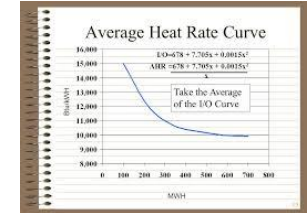
Calculate Actual Heat Rate

Data Reference: Formula

Settings...

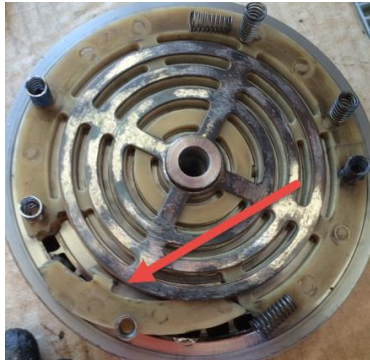
```
A=Unit_BHP;B=Unit_Fuel;C=Unit_BTU;[if badval(A) or badval(B) then 0 else if A <= 30 then 0 else (B*(1000*C*0.915))/A]
```

Unit_Heat_Rate_Actual	9843.68334570345	BTU(LHV)/BHP-hr
-----------------------	------------------	-----------------



Example of Predictive Analytics in PI AF – Expected vs Actual

Compression\Houma\Unit01\Gas Compressor\Discharge Temperature\Cylinder 1 Discharge Temperature



Found partially damaged compressor valve.
The valve was replaced in a planned & controlled manner.

#2 Preventive Maintenance (CBM)

- Usage-based PM's
 - Run hours
 - Start / Stop counts
 - Tonnage processed

 **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

San Francisco Public Utilities Commission

Results of Pilot



Asset Name	# of PMs: Scheduled Basis	# of PMs: Conditional Basis	# of unnecessary PMs Avoided
PUMP-1149	28	0	28
PUMP-1150	28	12	16
PUMP-1151	28	0	28
PUMP-1152	28	21	7
Totals	112	33	79

100 Main Pumps =
\$1.8MM Annually

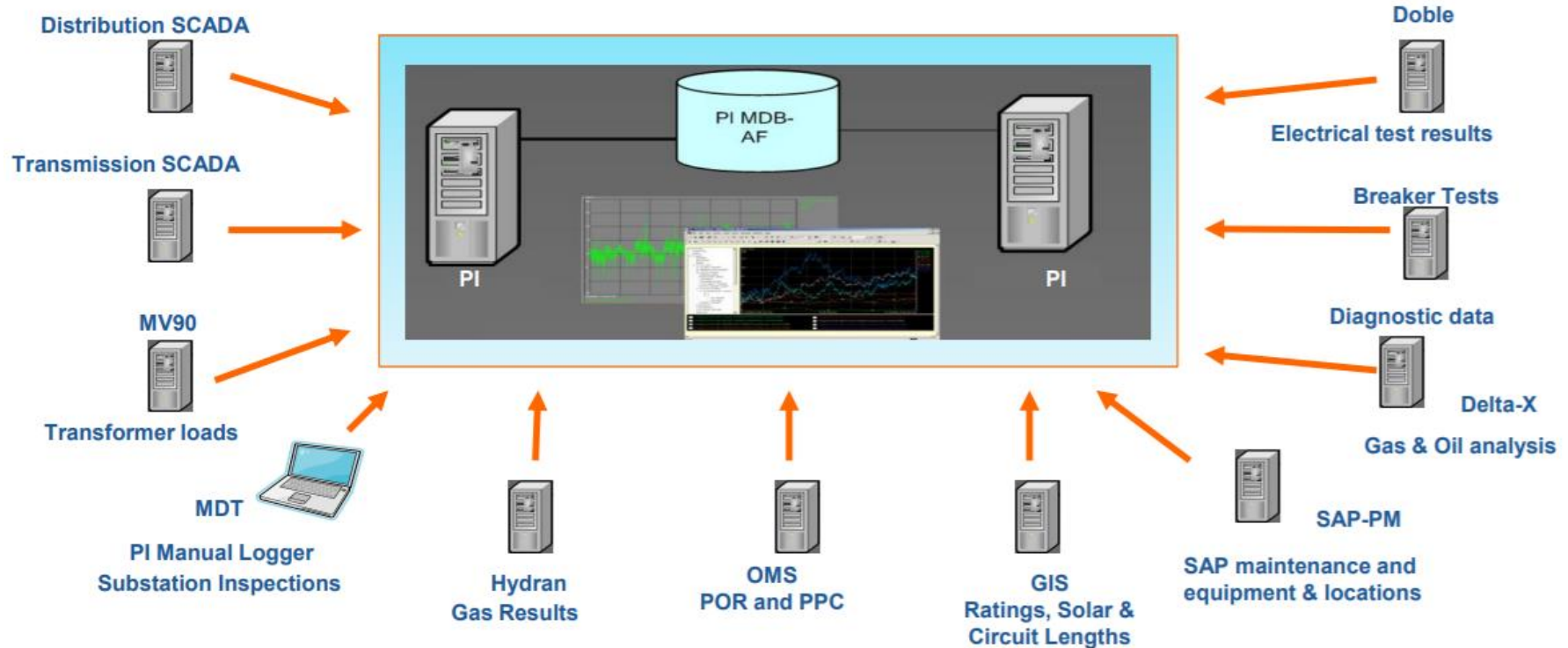
- Over the 28 month simulation, 79 unnecessary PM's identified
- Each set costs approximately \$2,100
- Annual savings for the 4 pumps is \$71,100

#3 Condition Assessment

$$CA = F1(M1) + F2(M2) + F3(M3) + \dots$$

Condition Assessment & Criticality
Determination

PSE&G – Consolidate & Correlate Data



Asset List with Score

Web Part Page - Microsoft Internet Explorer

File Edit View Favorites Tools Help Links Google Welcome to MyAssistant™ GIS Reports Information Central OAMS SP CMMS - MOSS eSHIP RtBaseline MOSS

Address http://njnwdev29/Asset%20Management2/WebPages/LtcsCA-A

PSEG LTC CA-Action New Summary

CA Records

Details	Division	Floc	Floc Descr
	CE	IPE-CE-SDN -1TRX	500-1 Transformer
	CE	IPE-CE-SDN -1TRX	500-1 Transformer
	CE	IPE-CE-SMN -1PM	132-1 Transformer
	CE	IPE-CE-DAY -UNIT 2	Unit Substation - 8002
	CE	IPE-CE-SCO -UNIT 1	Unit Substation - 4001
	CE	IPE-CE-SOS -T2	# 2 Transformer
	ME	IPE-ME-HNC -T2	# 2 Transformer
	SO	IPE-SO-BEA -T2	# 2 Transformer
	SO	IPE-SO-MAR -T1	# 1 Transformer
	SO	IPE-SO-SLA -T1LTC	220-1 Transformer Tap
	CE	IPE-CE-GSE -132-7	132-7 Transformer
	CE	IPE-CE-SBR -3TRH	220-3 Transformer
	CE	IPE-CE-SLI -41HL	H-2234
	CE	IPE-CE-SDN -2TRX	500-2 Transformer
	SO	IPE-SO-LAW -T2	# 2 Transformer
	SO	IPE-SO-MRO -T1	# 1 Transformer
	ME	IPE-ME-HAW -T2	# 2 Transformer
	CE	IPE-CE-GSE -1TRH	220-1 Transformer
	PA	IPE-PA-KIN -T2	# 2 Transformer
	CE	IPE-CE-POH -T2	# 2 Transformer
	PA	IPE-PA-HOE -T1	# 1 Transformer
	CE	IPE-CE-SBB -3TRX	500-3 Transformer
	CE	IPE-CE-SOS -T2	# 2 Transformer

PSEG LTC CA New Action Algorithm Details

Modify Shared Page

Nameplate

Online	Division	Station Code	Station	Station Type	Floc Descr	Equipment	Equipment Descr	Equipment Type	Construction Year	Serial Number	Manufacturer	Model Number
	Central	SDN	DEANS	X	500-1 Transformer	000000000010505424	Load Tap Changer A (LRS700)	E-LTC		1971 D596884	GENERAL ELECTRIC	LRS700

Content Editor Web Part

- Equipment Home Page
- View and Trend Equipment PI Points
- CA LTC New Action Algorithm Rules

Algorithm Factors

Factor	Raw Value	Case Value	Weight %	Score
Detectable Acetylene	10	10	25	2.5
Gas Rate of Change	3.67	2	15	0.3
High Total Gas	300	10	20	2
High Water	23	0	10	0
Low Dielectric	32.6	0	10	0
LTC Operations	34	0	10	0
LTC THRU NEUTRAL	0	0	10	0

CA Score

Score	maxScore	Ranking(%)	Peer Group
4.8	4.8	100	VACUUM

RtTrend

DeltaX Total Combustible Gas

Details	ApprType	Sample Date	CO	H2	Acetylene	Ethane	Ethylene	Methane	Combustible Gas
	LTC	07/27/2009	199	39	37	7	4	14	300
	LTC	06/11/2009	66	30	27	2	2	4	131
	LTC	03/13/2009	62	23	17	2	2	3	109
	LTC	12/17/2008	58	26	30	3	3	3	123
	LTC	06/26/2008	79	27	28	2	2	3	141

Showing 1 to 5 of 18

DeltaX Water

Details	ApprType	Sample Date	Fluid Temp (C)	Water
	LTC	07/27/2009	60	23
	LTC	06/11/2009	55	19
	LTC	03/13/2009	49	15
	LTC	12/17/2008	53	17
	LTC	06/26/2008	65	20

Showing 1 to 5 of 18

DeltaX Fluid

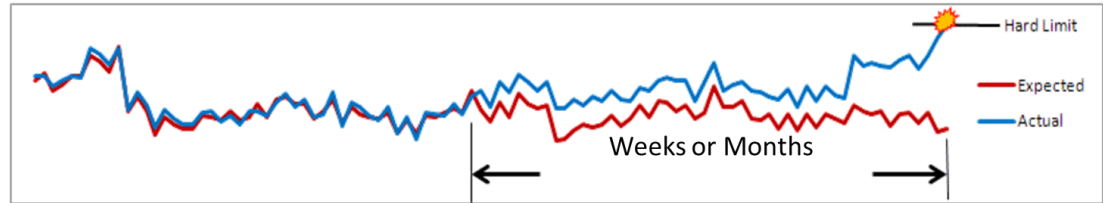
Details	ApprType	Sample Date	Fluid Temp (C)	D877	D1816
	LTC	07/10/2008		47.6	32.6
	LTC	06/13/2002		51.5	
	LTC	06/12/2000		55.4	
	LTC	05/10/2000			36.1
	LTC	07/15/1997			37.1

Done

Local Intranet

#4 Advanced Pattern Recognition (APR)

- Anomaly Detection
- Use history to build a model
- Statistical Techniques compare now to history



Exception Reporting

Define “Normal” Behavior (Model) for Each Point

Alarm on the Residual (Actual – Expected) > Limit

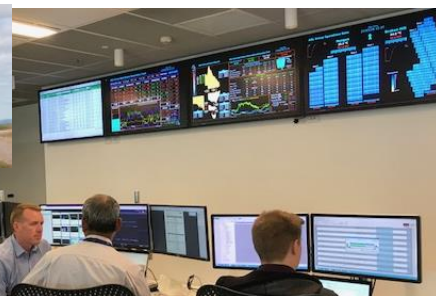
Focus on What’s Different - Anomalies

THE CHALLENGE – CALCULATE AN EXPECTED VALUE FOR EVERY LOAD AND AMBIENT CONDITION

Operational Diagnostics Centre



Reduce unplanned generation losses across a mixed technology portfolio of > 10,000 MW



CHALLENGE

Sense active failure modes at the earliest possible opportunity and take actions to avoid loss

- Data isolated and scattered
- Multiple SCADA technologies in play
- No access to real time data

SOLUTION

OSIsoft PI and APR

- ECG's PredictIT (APR) technology is fast & easy
- An Operational Diagnostics Centre (ODC) put experts & information together
- ODC also uses PI system for deep dive investigations

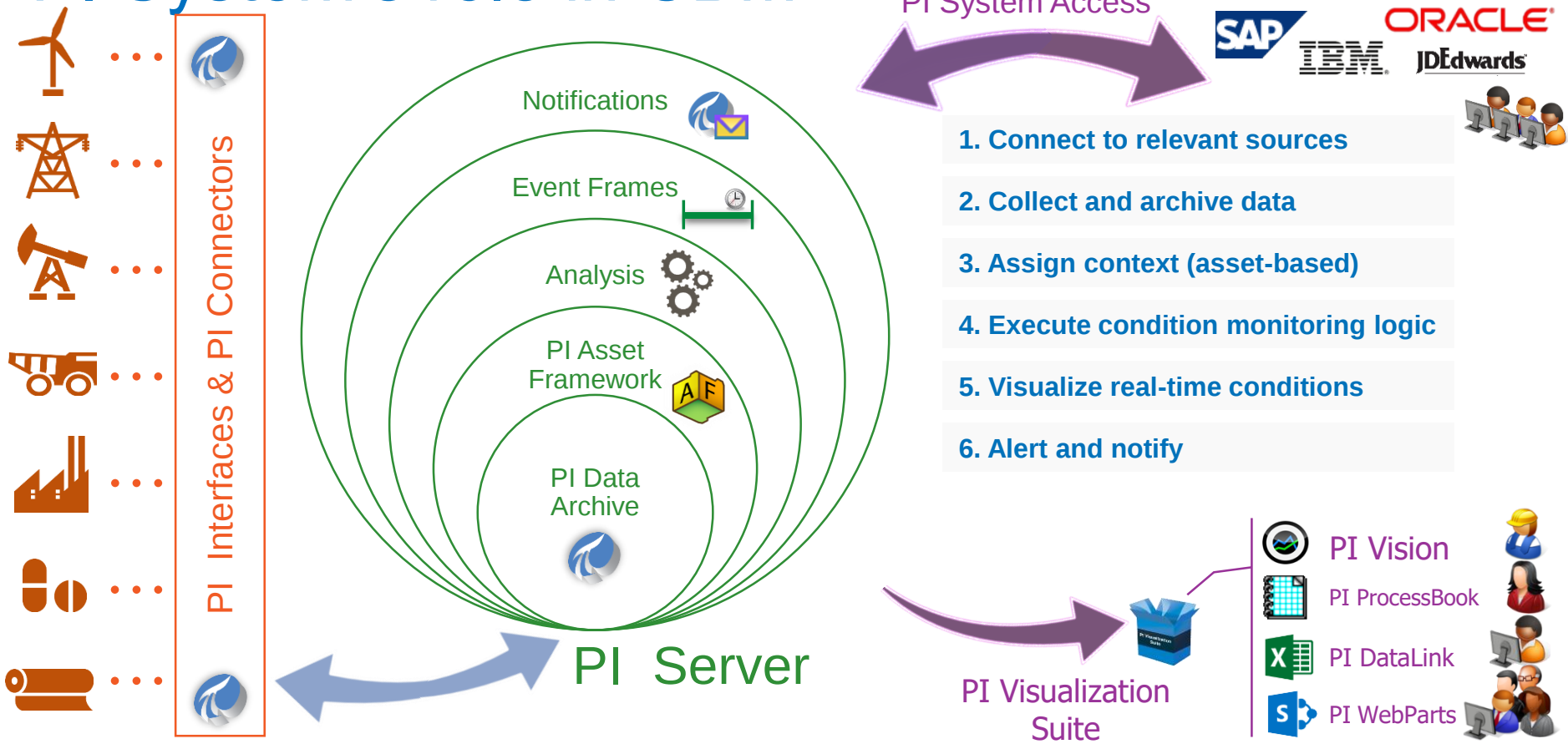
RESULTS

\$18.7M of avoided losses in 3 years (\$8.5M in one year)

- ODC delivers significant tangible benefits
- OSIsoft PI enables data transformation and other improvements

Presented at PI World San Francisco April 2018

PI System's role in CBM



Asset Context in PI AF

AF – Asset Framework

Categories for Attribute Groupings

Element Template

Attribute alias elements normalizes diverse tag / point names

Category	Name	Value
Category: <None>		
	In Service Date	1-Jan-13
	Last Service Date	8-Nov-13
	Manufacturer	GE
	Serial Number	1B395
Category: Bearing Temperatures		
	Inboard Bearing Temperature	135.006500244141 deg F
	Outboard Bearing Temperature	122.390983581543 deg F
Category: Flows		
	Auxiliary Steam Flow	14.8983793258667 lb
	Discharge Flow	1634.23645019531 k lb/hr
	Discharge Flow Total	757539.875 lb
	EXT Steam Flow Total	260660.078125 lb
	Flow entering economizer	3257.01762148438 k lb/hr
	Main Steam Flow	38.3094062805176 k lb/hr
Category: Limits		
	Bearing Vibration High Limit	2 mils
	Control Oil Pressure Low Limit	32 psi
	Discharge Flow Low Limit	1700 k lb/hr
	Suction Pressure High Limit	160 psi

Group by: ☒ Category ☐ Template

Name:

Description:

Configuration Item: ☐

Categories:

Default UOM:

Value Type:

Value:

Data Reference:

Settings...

Event Detection

Event Frame Template

Type = EF Generation

PE Functions

EF Start Trigger

Time True

Root Cause Child Events

Functions

StartTrigger

Duration

Generate child root cause event before parent event frame starts

Root Cause

Category

Scheduling

Trigger on

Evaluated at

StartTrigger true for:

Duration:

Name:

Category:

Scheduling:

Trigger on

Functions

Insert functions into the expression

All

Abs

Acos

And

Ascii

Asin

Atn

Atn2

Avg

BadVal

Bod

Bom

Bomm

Ceiling

Char

Compare

Concat

Convert

Cos

Cosh

Cot

Coth

Exp

Abs(number x)

Return the absolute value of an integer or real number.

Example: Abs(1)

Attributes

Monitoring Asset Conditions

The screenshot displays the OSisoft PIWorld monitoring interface. On the left, a hierarchical tree of assets is shown, including Boilers, Equipment, NuGreen, Houston, Crackin, Ec, Extruder, Milling, Little Rock, Tucson, Wichita, and Pumps. The main panel shows a detailed view of asset 10149651, which is a Boiler Feed Pump Vibration Anomaly. The asset is categorized under Location and has the following details:

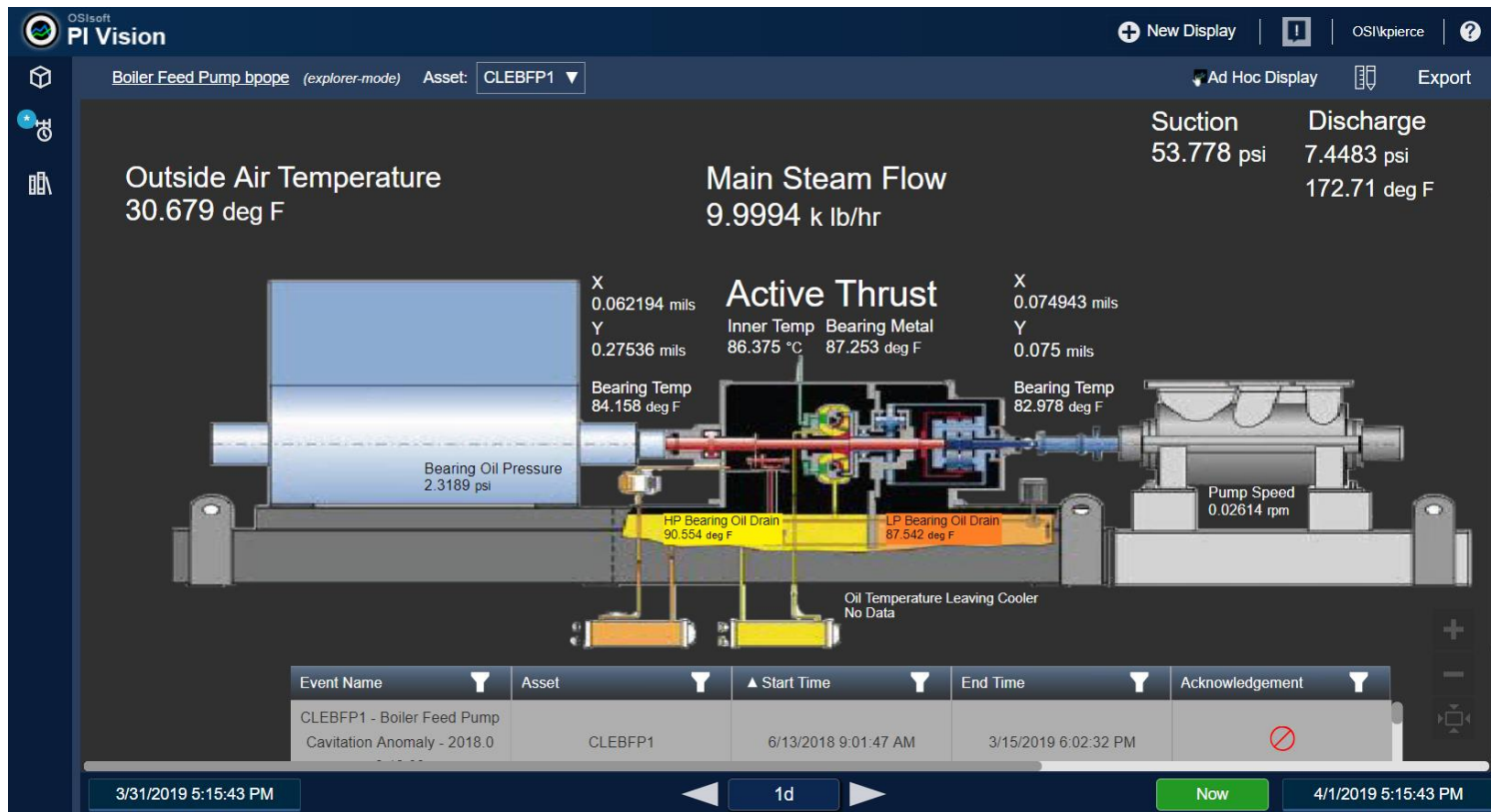
- Name:** 10149651
- Category:** Location
- Address:** 470 Beso Ln, San Antonio, TX
- Entity:** Cindy Bear
- Event Frame Template:** Boiler Feed Pump Vibration Anomaly
- Category:** Location
- Name:** Name
- Expression:** `if ('Inboard Bearing Vibration X' > 'Bearing Vibration High Limit') then True else if ('Outboard Bearing Vibration X' > 'Bearing Vibration High Limit') then True else if ('Outboard Bearing Vibration Y' > 'Bearing Vibration High Limit') then True else False`
- StartTrigger true for:** 0 Minutes
- Manufacturer:** L&T
- Service:** Residential

The screenshot shows an email alert from PIAerts&Company.com, dated Fri 12/12/2014 1:56 PM. The email is addressed to William Breich and contains the following information:

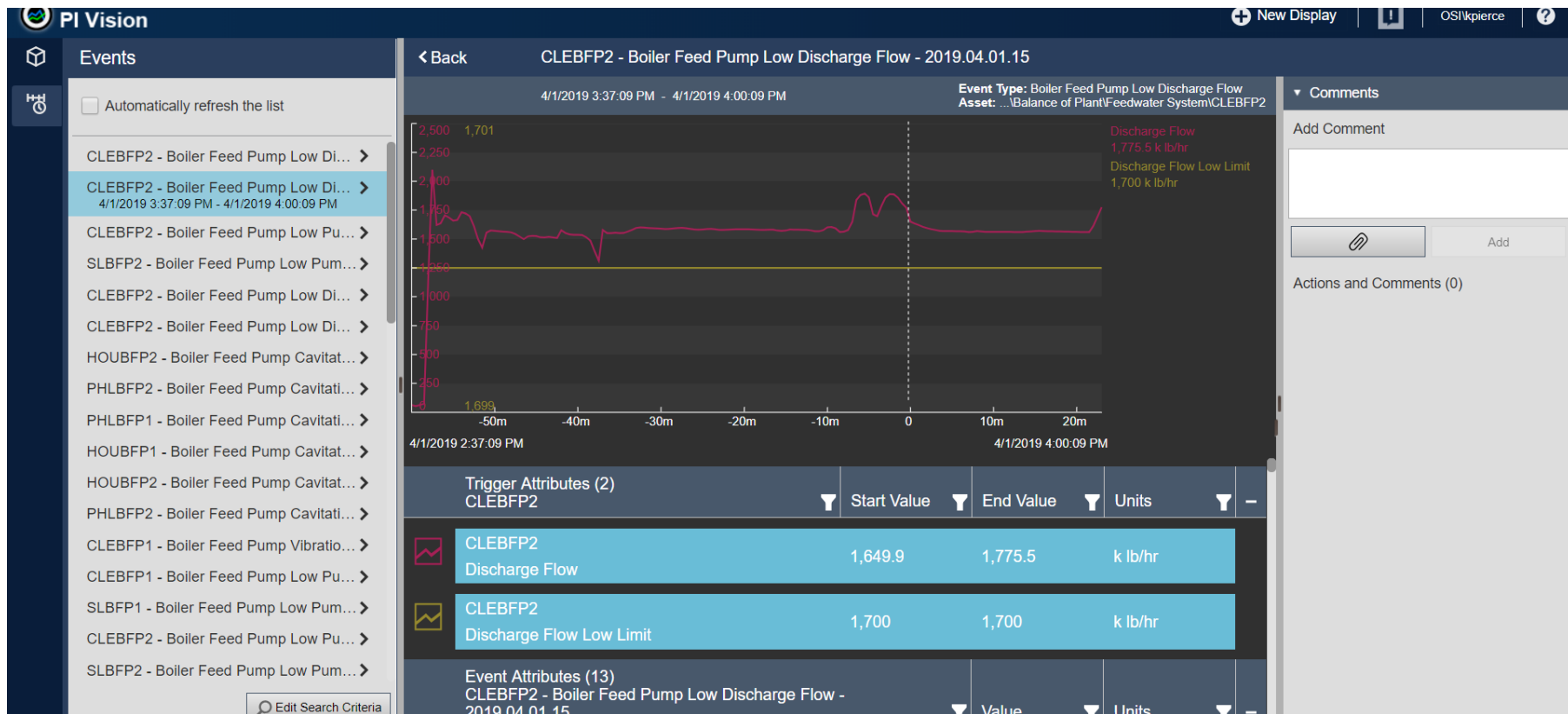
- Subject:** OSisoft - C Alarm - B14 - Black DS 30 Gal - Analysis
- Message:** You forwarded this message on 12/12/2014 1:59 PM. This message was sent with Low importance.
- Attachments:** Understanding Centerline Alarm Emails.docx, CMD Trend Screens.pdf
- OSisoft - A Alarm - B93 - Steamroller - Analysis**
- Acknowledge**
- Black DS 30 Gal triggered by test**
- Start Time:** 12/12/2014 3:56:24 PM Central Standard Time (GMT-06:00:00)
- Time to Fix:** 6 Hours
- See CMD Trend Screens.pdf for more details**
- Actions**
- Condition Fixed? (in timeframe)**
 - YES - Will receive email confirmation
 - NO - [Issue PIR](#)
- Attribute Alarm States**
- Fin Wind Torq SP1**
- Mid Range Torq SP0**
- Pin PW Over SP0**
- Trans Torq SP1**

For more details please see [PI Vision Display](#) and the [Boiler Feed Pump Overview](#) display

Boiler Feed Pump Overview



Boiler Feed Pump Event Analysis



Event Table Watchlist

OSisoft PI Vision

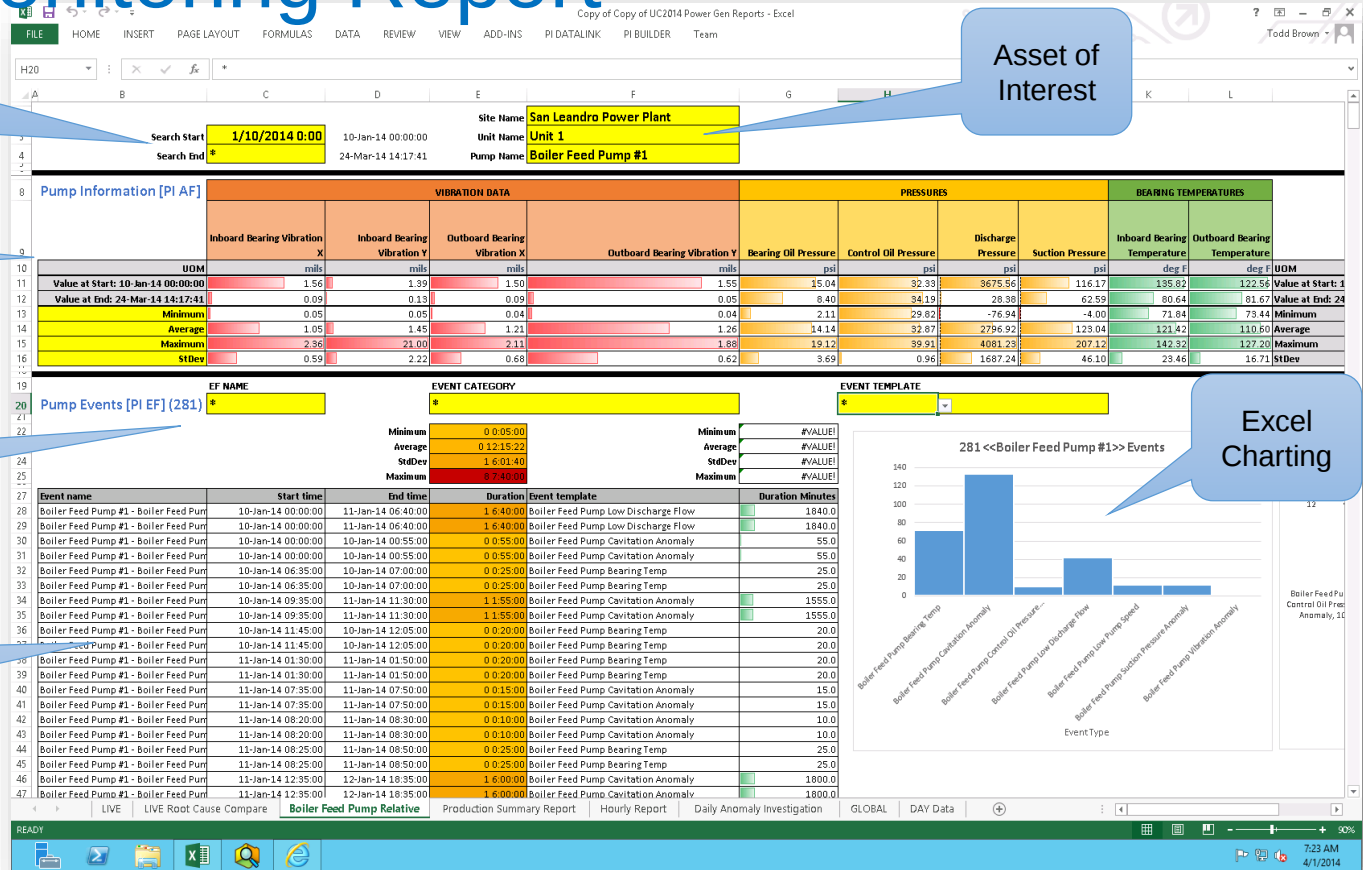
(explorer-mode) Asset: HOUBFP1

Ad Hoc Display Export

Event Name	Asset	Event Type	Start Time	End Time	Severity	Duration
HOUBFP1 - Boiler Feed Pump Low Discharge Flow - 2019.03.05.04	HOUBFP1	Boiler Feed Pump Low Discharge Flow	3/5/2019 5:22:22 AM	3/5/2019 5:31:52 AM	None	9m 29s
HOUBFP1 - Boiler Feed Pump Cavitation Anomaly - 2019.03.06.00	HOUBFP1	Boiler Feed Pump Cavitation Anomaly	3/6/2019 1:16:22 AM	3/6/2019 5:46:52 AM	None	4h 30m
HOUBFP1 - Boiler Feed Pump Cavitation Anomaly - 2019.03.06.04	HOUBFP1	Boiler Feed Pump Cavitation Anomaly	3/6/2019 5:47:52 AM	3/7/2019 1:54:22 AM	None	20h 6m
HOUBFP1 - Boiler Feed Pump Bearing Temp - 2019.03.06.09	HOUBFP1	Boiler Feed Pump Bearing Temp	3/6/2019 10:00:52 AM	3/6/2019 10:22:52 AM	None	21m 59s
HOUBFP1 - Boiler Feed Pump Bearing Temp - 2019.03.06.17	HOUBFP1	Boiler Feed Pump Bearing Temp	3/6/2019 6:13:22 PM	3/6/2019 6:46:52 PM	None	33m 29s
HOUBFP1 - Boiler Feed Pump Bearing Temp - 2019.03.06.21	HOUBFP1	Boiler Feed Pump Bearing Temp	3/6/2019 10:25:52 PM	3/6/2019 10:56:52 PM	None	31m
HOUBFP1 - Boiler Feed Pump Bearing Temp - 2019.03.07.00	HOUBFP1	Boiler Feed Pump Bearing Temp	3/7/2019 1:38:52 AM	3/7/2019 2:03:22 AM	None	24m 30s
HOUBFP1 - Boiler Feed Pump Cavitation Anomaly - 2019.03.07.01	HOUBFP1	Boiler Feed Pump Cavitation Anomaly	3/7/2019 2:01:52 AM	3/7/2019 2:03:52 AM	None	1m 59s

3/4/2019 5:22:47 PM 7d Now 3/11/2019 5:22:47 PM

Condition Monitoring Report



PI System - CBM Resources

- [Corporate Site](#) – General info and use case search, webinars,...
- [CBM Guidebook](#) – Reference material on CBM and Condition Monitoring
- [Technical Support](#) – technical resources, downloads, questions,...
- [PI Square and CBM](#) – Lots of resources
- [PI Community](#) – Peer discussions and OSIsoft moderation, industry groups, development resources, whitepapers, webinars,...
- [YouTube](#) – training and introduction videos
- [PI Learning](#) – online courses, course materials,....
- [Incorporating machine condition monitoring data](#)

CBM Customer References

Portland General Electric - power generation [Experience-using-the-PI-System-for-Full-Featured-Vibration-Monitoring](#)

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-Fraco-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)

CBM Ideas for Workshop

- Pump / Motor Usage
- Pump / Motor Start – Stop Cycles, Duty Cycles
- Calculate Efficiencies, Anomalies, etc.
- Energy per Unit Processed (e.g. MG/D)
- Predictive / Maintenance Event Detection & Analyses
- SAP, Maximo etc. integration

Asset Monitoring and Condition-based Maintenance (CBM) with the PI System



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Questions?

Please wait for
the **microphone**

State your
name & company



Please remember to...

Complete Survey!

Navigate to this session in
mobile agenda for survey

