SmartGen Continuous Monitoring-Advanced Pattern Recognition-PlantView Program Implementation @ Smith Energy Complex

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Presentation Overview:

- SmartGen Equipment Monitoring
- Advanced Pattern Recognition
- EtaPRO Thermal Performance Monitoring
- PlantView Program

CBM Program Owner Smith Energy Complex Hamlet, NC

Past experiences

Old School PdM guy-go out there collect the data, look-touch-smell-listen to your machines

Program Implementation Background

- **Drivers**

  - **Reliability & Workforce Challenges**

    - Plant Closures, Aging Coal Fleet & New Complex Equipment

    - Market Dynamics – longer CC runs & cycling coal plants

  - **Challenges w/ Reliability Programs** –

    - Existing programs – 80% manual data collection/review

    - M&D Center – utilizes existing process instrumentation

  - **Shaping the Future**

    - Technology Innovation - new wireless, sensors, diagnostics

    - Workforce Utilization – higher value analytical tasks

SmartGen – Advanced Condition Monitoring

Integrating Energy, Space, & Industrial Technologies

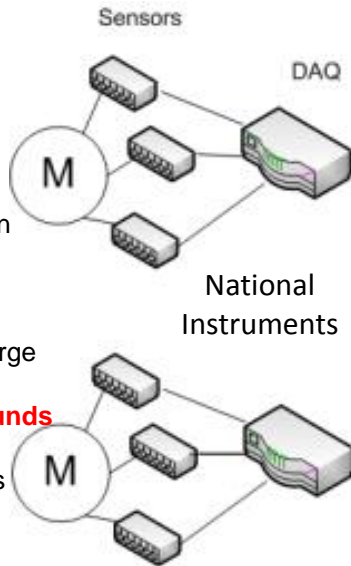*Draper Labs SmartGen Project*

EPRI SmartM&D TC Project

SmartGen Scope

Expanded Instrumentation
More equipment monitoring using wireless technology and low cost sensors at a fraction of the cost of conventional instrumentation.

Enhanced Diagnostic/Risk Capabilities
-Implement EPRI Diagnostic & Risk Advisors
-M&D Centers – more info & diagnostic advise
- PdM - more analytical – less data collection
- Operations – reduce rounds w/ new sensors
- Engineering – enhanced Risk Analysis

➢**Sensors**
➢Vibration
➢Temp
➢Oil
➢Motor
➢Ultrasound
➢IR
➢Leak Detection
➢Press
➢DGA
➢EMI
➢Partial Discharge

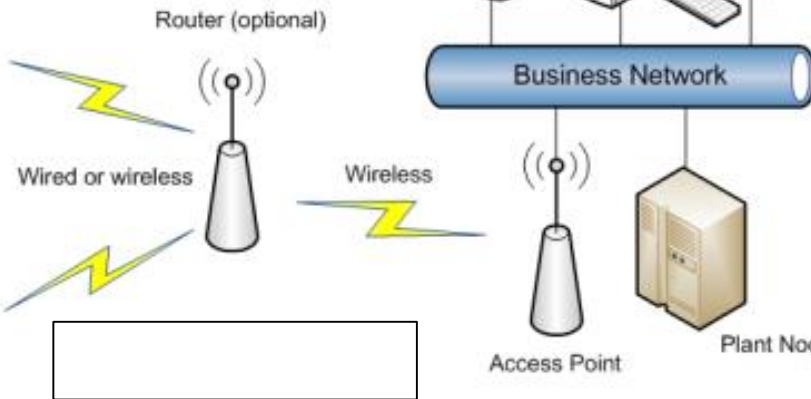➢**Operator Rounds**
➢Cameras
➢Smell Sensors
➢Microphones

New Plant M&D Network:
Wired/wireless network to key remote Plant locations, like equipment areas,

Sensors
DAQ
M
National Instruments
Router (optional)
Wired or wireless
Wireless
Business Network
Access Point
Plant Node
M

M&D Center

SmartGen Asset Health Management Software
-Integrated Equipment Condition Monitoring
-Data Fusion & Visualization
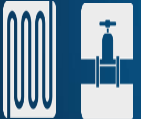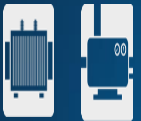-Smart Diagnostics and Risk Advisor
- Link to Long Range Planning - Budget

Integrate Diagnostic Systems
Leak detection, stress wave, partial discharge, DGA, Motor analysis, etc…

Leveraging EPRI Collaboration for Software & Sensor Development

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Smart M&D Overview

Sensors

- Accelerometers
- Temperature Sensors
- Oil Analysis Sensors
- Thermal Cameras
- Proximity Probes
- Miscellaneous

Monitoring Systems

CompactRIO

Plant Servers

NI Software

Database Historian

Corporate Monitoring and Diagnostics (M&D) Center

PlantView™ Fleet-Wide Dashboard

InStep PRiSM™ Pattern Recognition

GP EtaPRO™ Efficiency Monitoring & Thermal Modeling

EPRI Fault Signature Database
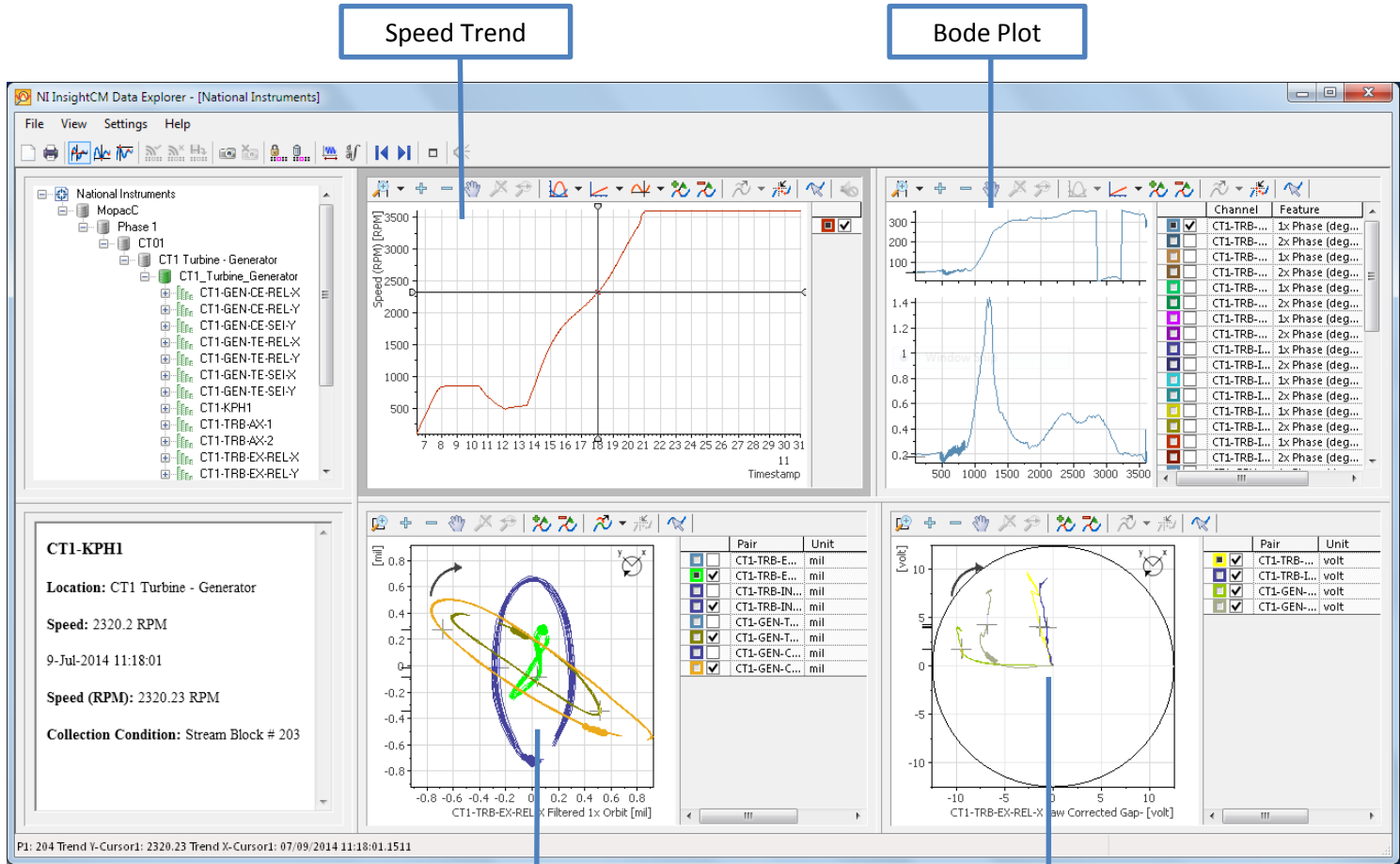

10,000+ Assets | 30,000+ Sensors | 2,000+ Nodes | ~60 Plants | M&D Centers

SmartGen Desktop-Turbine Generator/Large Rotating Equipment Monitoring

Speed Trend

Bode Plot

Orbit
• Display Multiple Orbits across multiple planes

Shaft Centerline

SmartGen Desktop-Typical Equipment Monitoring Screen

Site Hierarchy

Hear your data

Feature Trend Viewer

Data Annotations

Detailed Data Description

Time Waveform Viewer

Spectrum View
• Includes Waterfall, Orbit and Full Spectrum Plots
• Harmonic/Sideband Cursors

SmartGen Desktop Data Options
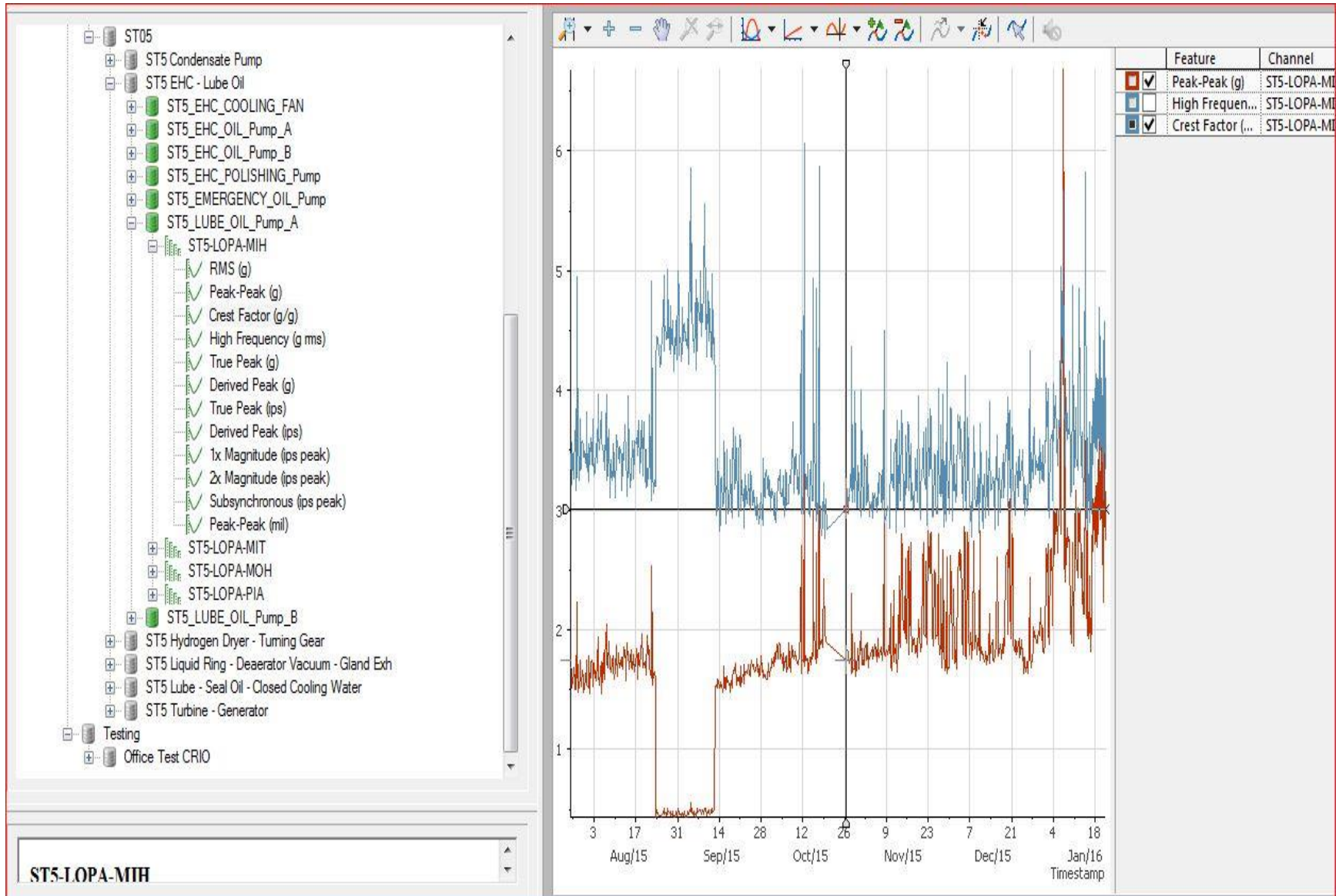
What to do with all this data?

- ***Challenges***

  - Large number of sensors/channels

  - Limited validation resources (People)

- Incomplete machine operating status information
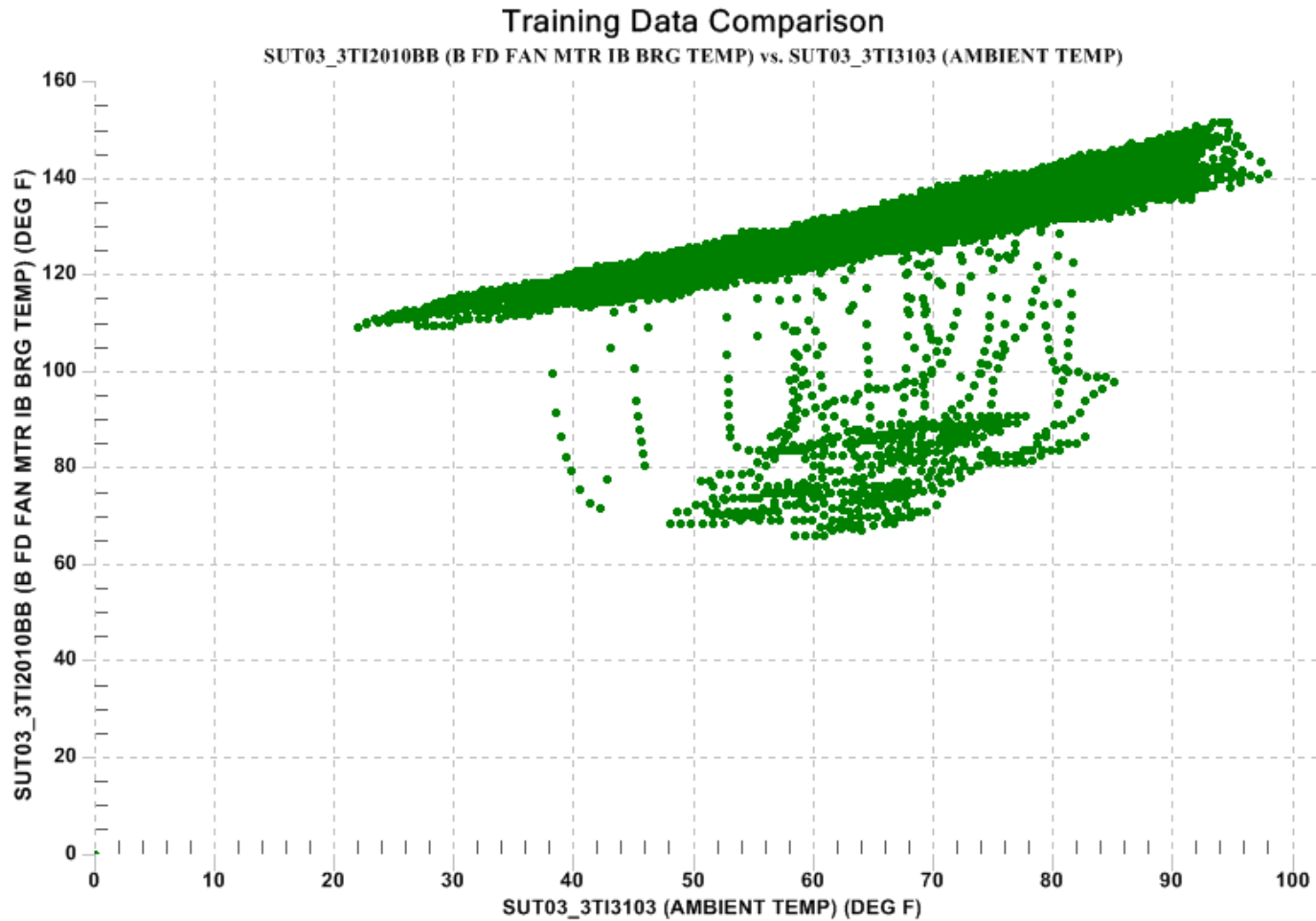
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Solution:

- Automated data screening

- Manual testing of a random sample of channels

- Trend Analysis to identify intermittent problems

- Operating Status from Vibration Data

Advanced Pattern Recognition

- The Duke M&D Center uses Advanced Pattern Recognition software to monitor plant and equipment operation. The software detects subtle deviations from normal operation that can be used as early indicators of future problems

- The M&D Center partners with the stations and fleet technical support to capture their knowledge of the equipment. This knowledge is used in our models to free the plants from repetitive monitoring. This approach reinforces the focus of more diagnosis and less routine data review on correctly functioning machines

  - Portion of fleet monitored by APR

    - 43,000MW, 76.4B MWhr in 2014

  - 234 Units, (44 Steam, 13 CC's, 167 CT's, 8 PS, 1 Hydro so far)

    - >8000 APR Models, (5459 Classic, 2462 SG)

    - >50,000 Points monitored every 5 minutes

      - 53 PI servers
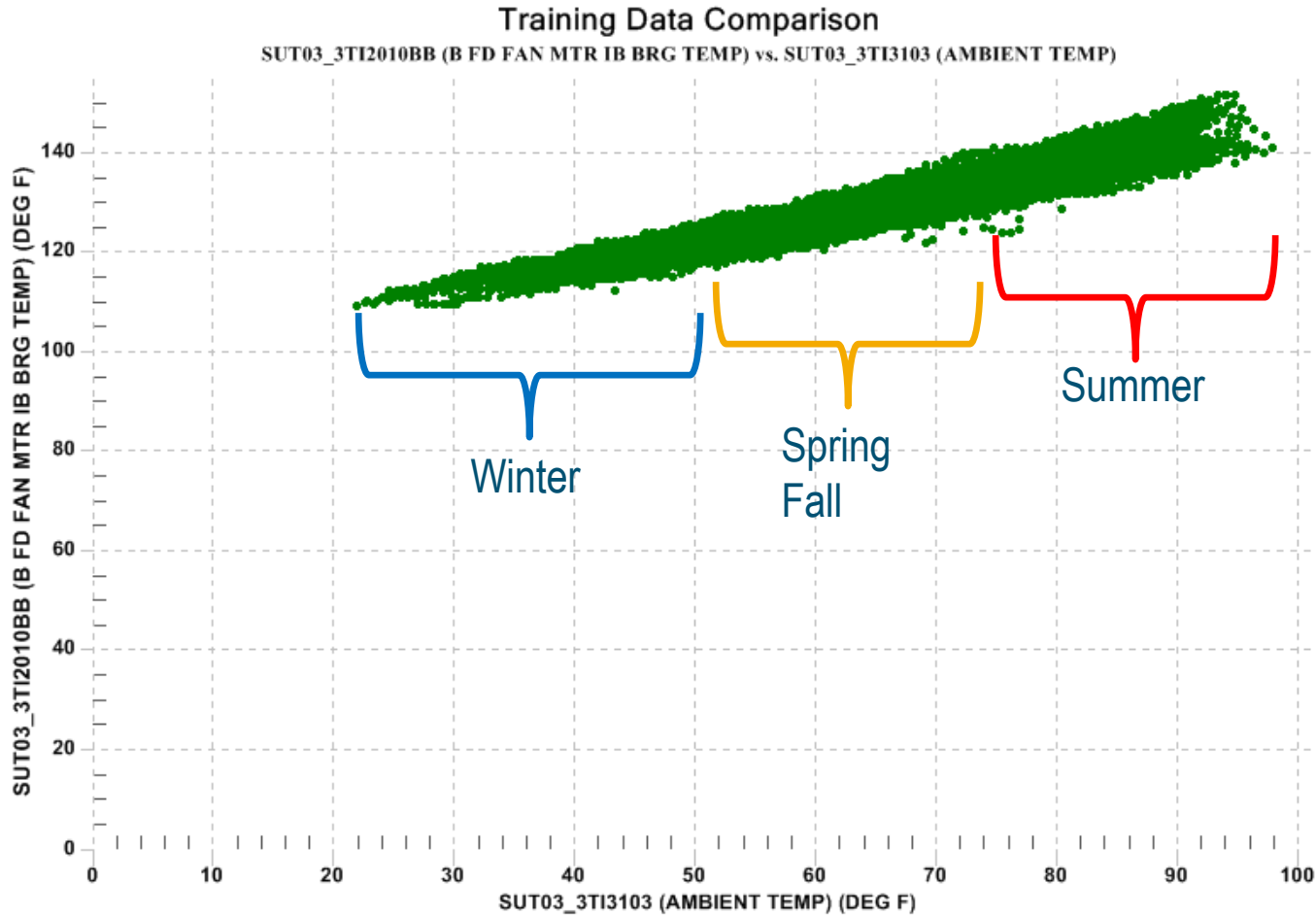
APR Modeling Process – Raw Data

- Pull raw data from Pi
- Typically data sets will be 5 min samples for 1 year

Training Data Comparison
SUT03_3TI2010BB (B FD FAN MTR IB BRG TEMP) vs. SUT03_3TI3103 (AMBIENT TEMP)

(scatter plot: y-axis "SUT03_3TI2010BB (B FD FAN MTR IB BRG TEMP) (DEG F)" ranging 0 to 160; x-axis "SUT03_3TI3103 (AMBIENT TEMP) (DEG F)" ranging 0 to 100)
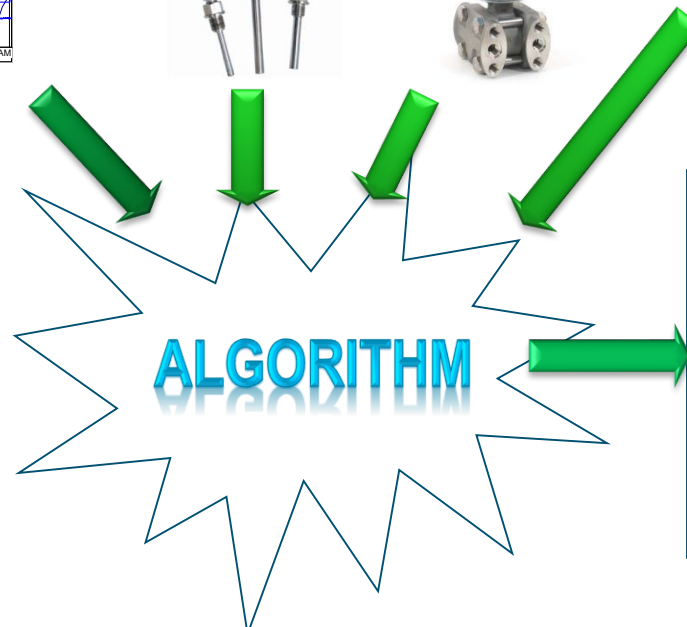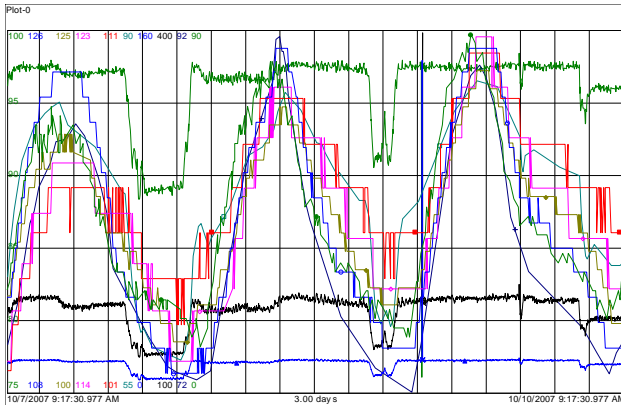
- Cleaned data set represents operation during all ambient / MW loading conditions

APR Modeling Process – Model Algorithm

- Feed historical data to APR algorithm to build prediction
- Feed Real-time values to APR algorithm every 5 minutes
- Algorithm predicts output values and compares real time with predicted

ALGORITHM

Predicted values
- **Fan OB Bearing Temp**
- **Fan IB Bearing Temp**
- **Motor IB Bearing Temp**
- **Motor OB Bearing Temp**
- **Motor Winding Temp**
- **Amps**
- **Discharge Press**

APR Modeling Process – Alert Generation

- Subtract actual value from the predicted (expected) value to calculate the residual

Profile: Rox 2D BCWP
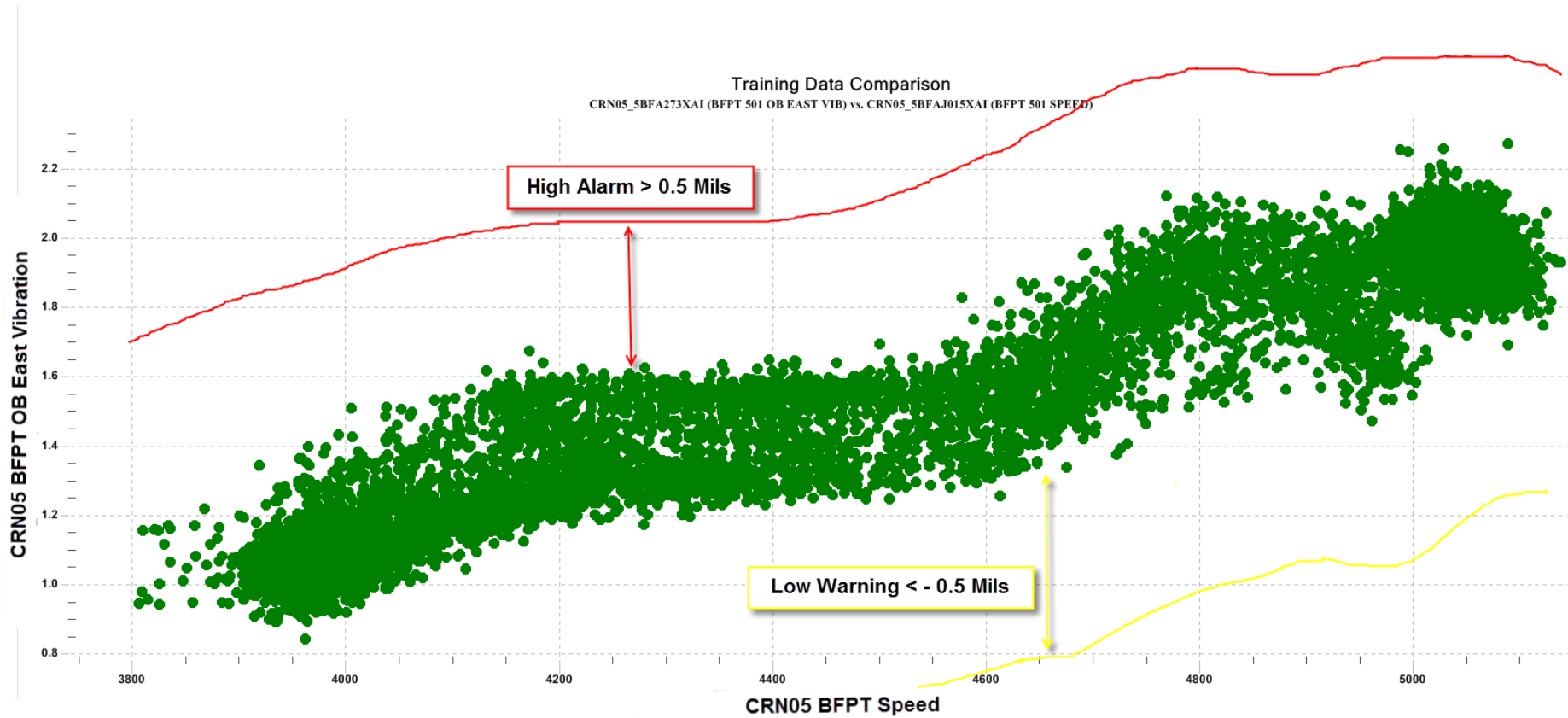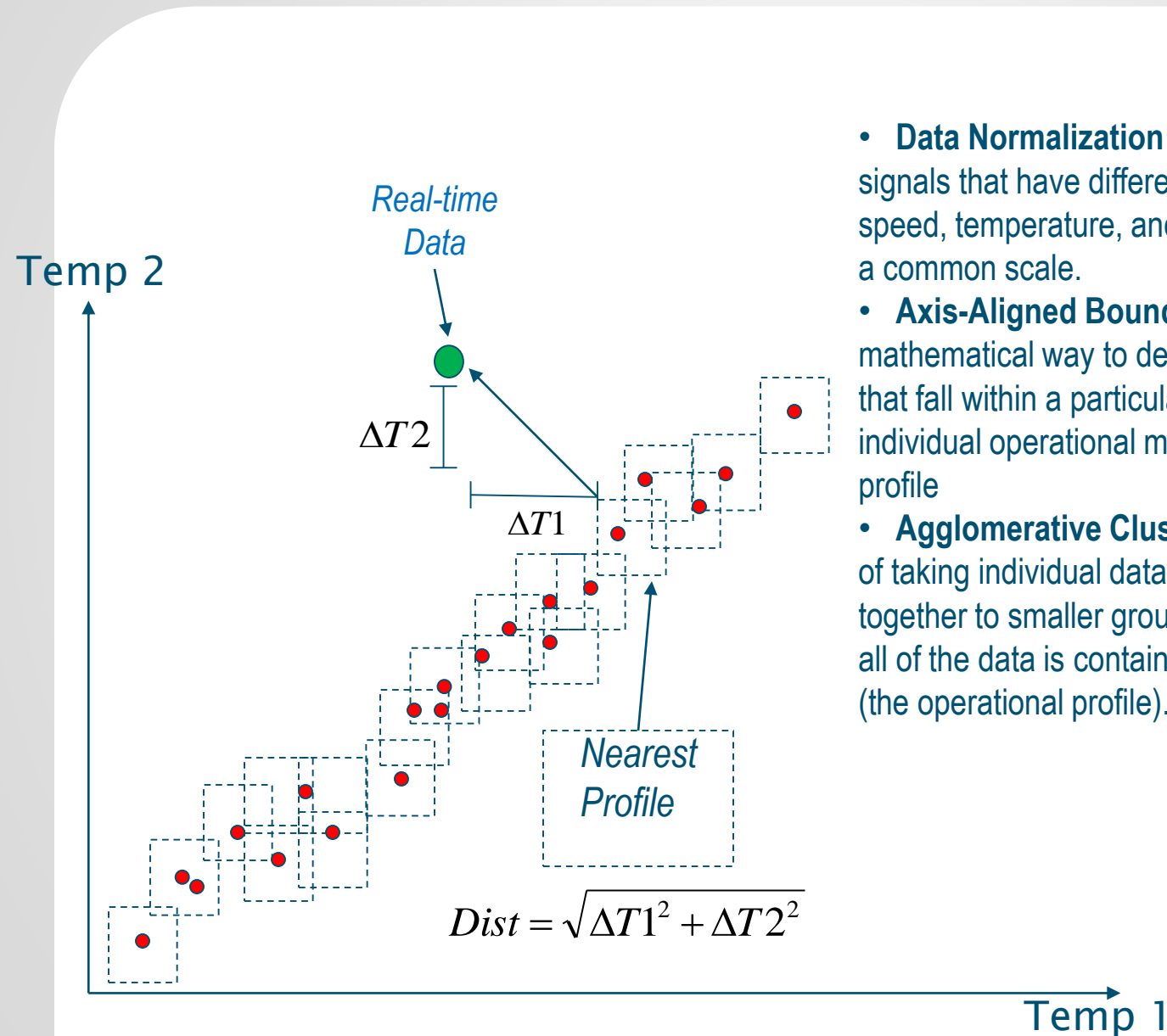Signal: ROX02_TE-232DA
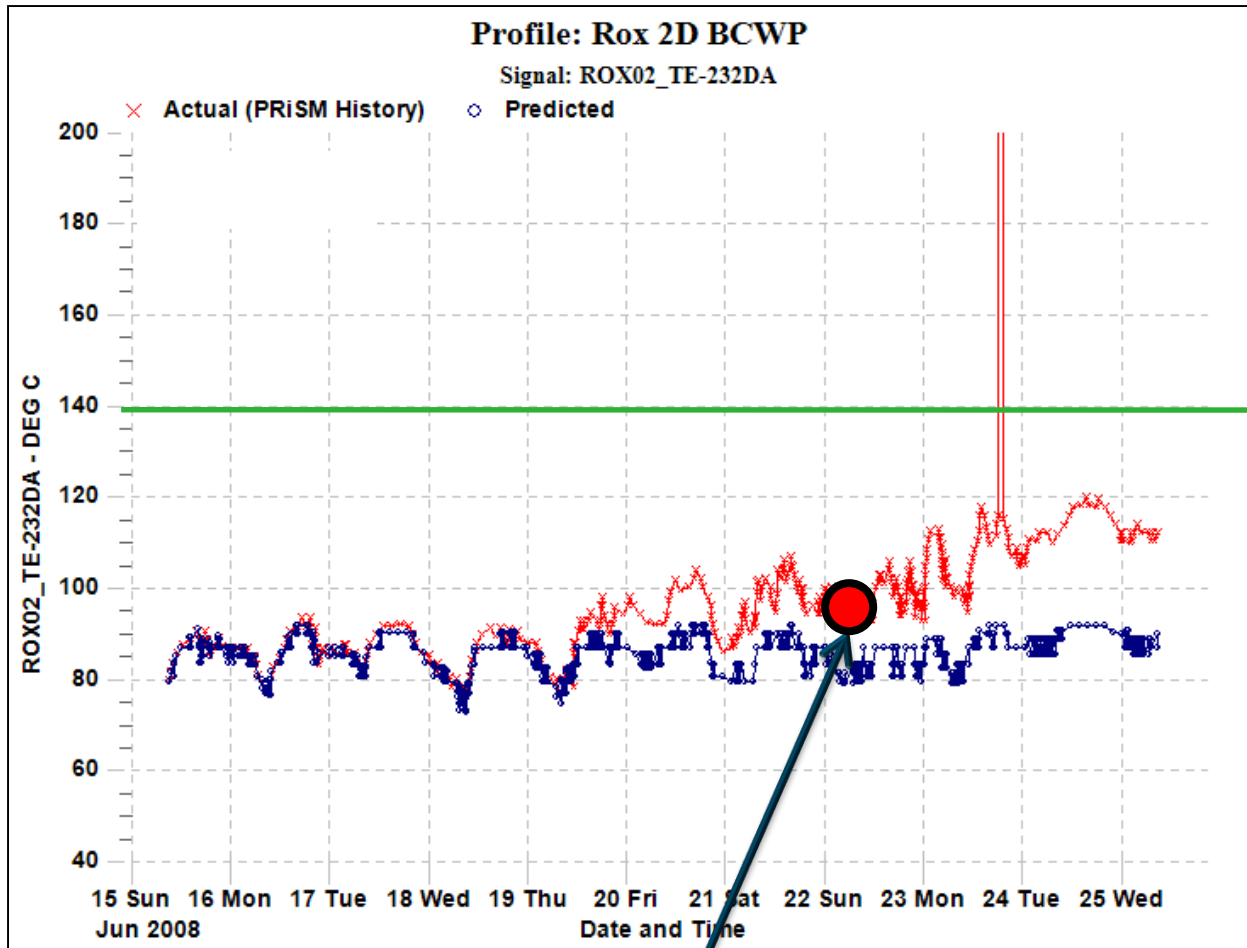
Traditional Alarm @ 140 C

Actual Value

- Predicted Value

= Residual

First Pattern Recognition alarm, residual exceeded 10 C
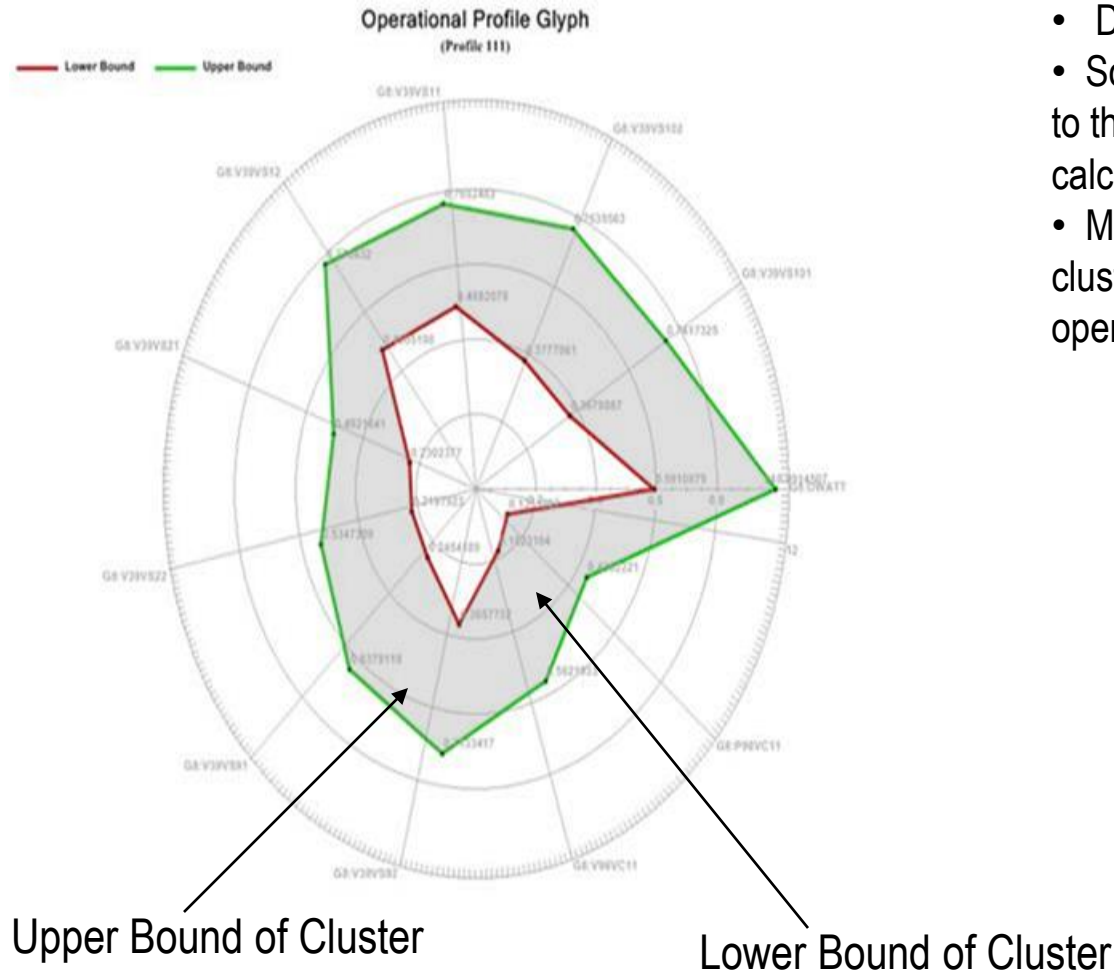
Modeling Process – Training Data Set

Training Data Comparison
CRN05_5BFA273XAI (BFPT 501 OB EAST VIB) vs. CRN05_5BFAJ015XAI (BFPT 501 SPEED)

High Alarm > 0.5 Mils

Low Warning < - 0.5 Mils

CRN05 BFPT OB East Vibration

CRN05 BFPT Speed

Modeling Process – Forming Clusters

Temp 2

Real-time Data

$\Delta T2$

$\Delta T1$

Nearest Profile

$$Dist = \sqrt{\Delta T1^2 + \Delta T2^2}$$

Temp 1

- **Data Normalization** - "min-max normalization" allows signals that have different units of measure (for example: speed, temperature, and pressure) to be compared using a common scale.
- **Axis-Aligned Bounding Boxes** - (AABB) a simple mathematical way to describe a collection of data values that fall within a particular range. These are the individual operational modes that make up an operational profile
- **Agglomerative Clustering** - mathematical technique of taking individual data samples, and putting them together to smaller groups (the operational modes) until all of the data is contained in a collection of those groups (the operational profile).

Modeling Process – Cluster Example

Operational Profile Glyph
(Profile 111)

Upper Bound of Cluster

Lower Bound of Cluster

- Single cluster with 10 vibration tags
- Data is normalized
- Software "picks" cluster that is closest to the real-time data for residual calculations
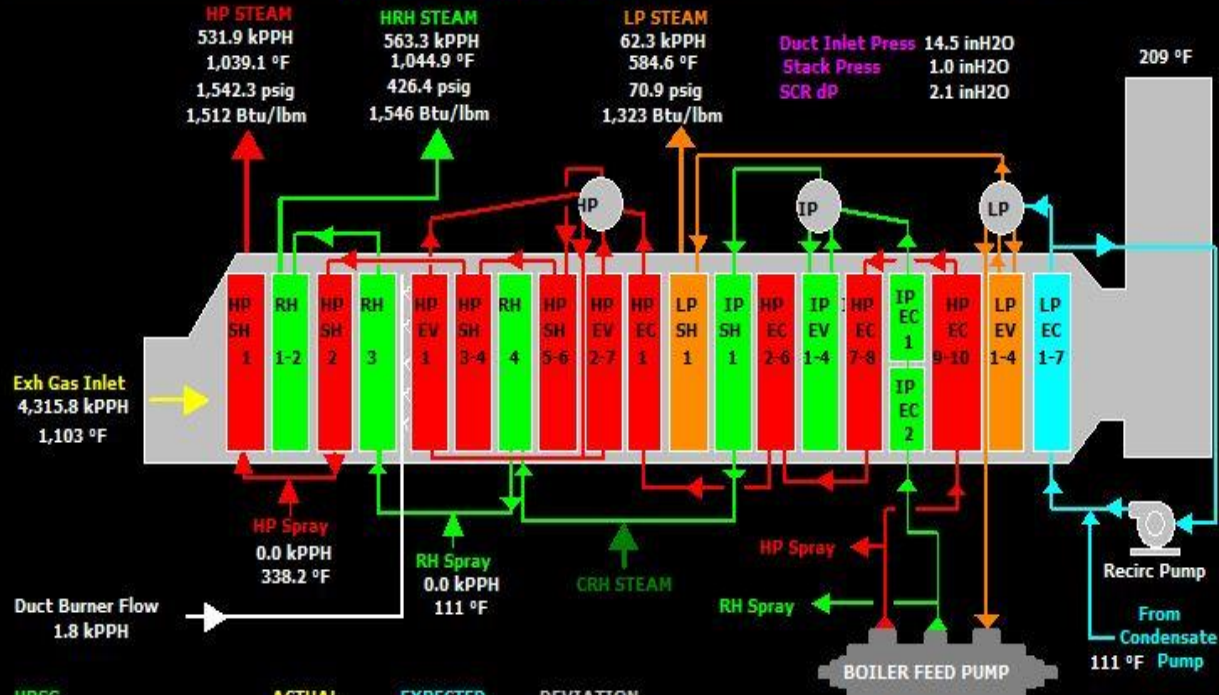- Models typically have 100-200 clusters to represent all modes of operation

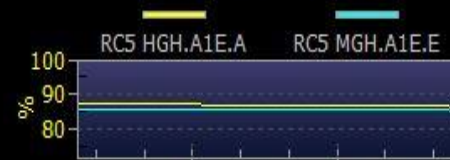# EtaPRO Thermal Performance Monitoring

EtaPRO Thermal Performance Monitoring

PlantView Program

**PlantView was developed by EPRI and Progress Energy.
The program is a software program used to configure plant equipment, develop a monitoring plan for each component and to document the findings of each monitoring task
Component and System Engineers use PlantView as the repository for all inspections, test reports and condition based evaluations**

**PlantView replaces the traditional PM work order process
and eliminates duplicate paperwork**

PlantView Program

Equipment Design Information

Equipment # 11776 / Server # 1
Unit # 770 / System # 4072

[Add] [Update]

Field	Value		
Equipment	Lube Oil Motor #1	Technologies	Acoustic / Ultrasonic Monitoring
			Advanced Pattern Recognition
Plant/Unit	Richmond ST-4		Functional Testing
			Mechanical Inspection
System	431 - ST Lube Oil system		SmartGen
			Borescope
Description	MAIN OIL PUMP MOTOR (A)		Electrical Testing
			Field Performance Testing
			Infrared Thermography
Location			Insulating Oil Analysis
Tag Number	MOT	PdM Status	Enabled

PlantView Connectivity: System Identifiers & Configuration Parameters

Field	Value
Passport Identifier	RIC·ST4·431·MOT·4-1-MP-0201A·
CMAX Model Name	
Passport ECode	0001049759
System #3 Identifer	
System #4 Identifer	

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PlantView Program

Diagnostic Technologies: Frequency, Collection & Data Collection Compliance

Technology ⇕	Frequency	Past Due	Collection	DCC Required Equipment Status
Acoustic / Ultrasonic Monitoring	7000	7001	On-Demand/Auto ⌄	Same as Technology Setting ⌄
Advanced Pattern Recognition	7000	7001	On-Demand/Auto ⌄	Same as Technology Setting ⌄
Field Performance Testing	7000	7001	On-Demand ⌄	Same as Technology Setting ⌄
Infrared Thermography	180	240	Manual/Auto ⌄	Same as Technology Setting ⌄
Observation - Maintenance	7000	7001	On-Demand ⌄	Same as Technology Setting ⌄
Observation - Operator	7000	7001	On-Demand ⌄	Same as Technology Setting ⌄
Observation - System Owner	7000	7001	On-Demand ⌄	Same as Technology Setting ⌄
Off-line Motor Testing	365	455	Manual ⌄	Same as Technology Setting ⌄
On-line Motor Testing	365	455	Manual/Auto ⌄	Same as Technology Setting ⌄
On-line Performance Monitoring	7000	7001	On-Demand/Auto ⌄	Same as Technology Setting ⌄
Process Data	7000	7001	On-Demand/Auto ⌄	Same as Technology Setting ⌄
Vibration Analysis	180	240	Manual/Auto ⌄	Same as Technology Setting ⌄

Data Collection Compliance (Integrated Equipment Status: Equipment In Service)

Status	In Service ⌄	Metrics	Collected - Tier1 ⌄

PlantView Program

PlantView Program

If a Tech Exam is entered that is not acceptable the CBM program owner can enter a case history and cost benefit analysis using the included templates.

After a series of Tech Exams have been entered into PlantView the System or Equipment Owner (or their designee) performs an equipment assessment for each component that documents equipment condition.

M & D Center Notifications

When the Prism software flags a process parameter as being off normal the M&D center verifies the condition and notifies the site CBM owner of the issue. The site logs the notification and determines if there is plant work order in the CMMS system to address the issue. If not a work order is generated and scheduled for work and a Tech Exam entered into PlantView. This process is also applies to the notifications from the equipment OEM diagnostic centers (GE/Siemens). At Smith the spreadsheet that is used to capture these notifications is sent out monthly to plant management for review.

M & D Center Notifications

	M&D Center Log-CBM Program						
Date	**Note Text**	**Priority**	**Category**	**Status**	**Date Closed**	**Recommedation/Resolution**
1/13/2016	**Siemen's Notification:** Blade Path Temperature 11 A (52MBA10CT111A_XQ01) indicates a locked value of 1,115 °F. System 392 TE39211A	Normal	Instrument	N/A		WO 9615977
12/30/2015	RCH09 CT Generator Turbine End Bearing Metal Temperature A has dropped to 32 degrees, indicating an issue with the sensor or connections.- *duplicate notification*	N/A	N/A	N/A	N/A	**N/A**
12/29/2015	**Siemen's Notification:** After the GT start the PDC noted that Inlet Filter Delta Pressure High (1=High) @52MBL10CP083_XG01 was high on 2 occasions at 0815 for 4 hours and at 2130 for the remainder of the operating day. This alarm may suggest inlet filter clogging or wetting.	Normal	Filter	*Closed*	1/15/16	WO 9432976 replaced switch and calibrated-indication looks corrrect in PI
12/20/2015	**Siemens's notification:** CT thrust bearing metal temperatures fail intermittemtly fail low: TE 39236A/39236B/39235A/39235B	Normal	Instrument	Open		Issue reported priviously-WO 8225580
12/20/2015	**Siemens's notification:** Generator TE Bearing Metal temp TE 39271A is flat lined at 32 degrees F.	Normal	Instrument	Open		WO 9464014
12/14/2015	GE Notification: U7 Gas Control Valve numbers 2 and 3 are indicating a current measurement that is out of the prescribed limits.	Normal	Control Valve	Open		WO 9413851
12/11/2015	Combustor 16 Premix Flashback Temperature 1 (52MBM10CT031_XQ01T) shows a -1 °F value	Normal	Instrument	Open		WO 9405667-2nd failure of this TE (see WO8219582-1) -PI trends indicate that channel A of the U10 16 Premix Flashback Temperature took a step change to -757 degrees on 12/09/15 @1500 hours. Channel B is indicating -24 degrees which is also out of the grouping of these temperature instruments.

SmartGen/APR/PlantView Site PdM Program Interface

SmartGen/APR/PlantView will alter the traditional roles and responsibilities of the site PdM/CBM program owner

- *Transition from a monitoring based program to a diagnostic based program*

- *APR allows for early detection of process anomalies*

- *Expand monitoring program to utilize alternate monitoring technologies*

- *Use PdM technologies to enhance monitoring scope*

- *Allows for the dedication of the staff's time to solve complex chronic problems with failure investigations and improved diagnosis*

- *PlantView Program is the basis of the CBM program-eliminates the traditional PM based data collection routine*

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In the future?

Cell Phone App???!!!!!

Questions?