Applied Advanced Pattern Recognition Technology

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CURTISS WRIGHT Flow Control Company
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MIDWEST GENERATION

Presentation Topics

- Overview of Midwest Generation's Monitoring Plan – "Work in Progress"
- Technology Evaluation
- Monitoring Focus
- Advanced Pattern Recognition Technology Deployment
- Project Status – January 2009
- Q&A

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MIDWEST GENERATION

Our Mix of Generation: Thermal

- 8 coal-fired plants
  - 6 in Illinois (MWGen)
  - 1 in Pennsylvania
  - 1 in West Virginia

- 9 gas-fired plants in California and Washington

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MIDWEST GENERATION

About Edison Mission Group

- A major Independent Power Producer (IPP), headquartered in Irvine, CA
- 30 Power Plants, 10,634 megawatts
- Energy marketing and trading center in Boston, MA
- Sister company to Southern California Edison

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MIDWEST GENERATION

Wind: A New Generation in Generation!

- 18 Wind farms in Iowa, Minnesota, New Mexico, Oklahoma, Pennsylvania, Texas and Wyoming.
- Projects are pending in Illinois, Maine, Maryland, Nebraska, New York, Pennsylvania, Utah, West Virginia, Wisconsin and Wyoming.
- We are one of the fastest growing developers of renewable energy.

Midwest Generation WT Monitoring Objectives

1. **Obtain an earlier warning on impending problems before a failure occurs**
   - **Prioritize tower inspections and analysis trouble shooting**
   - **Schedule Maintenance – Reduce unplanned events**
   - **Optimize crane usage**
   - **Reduce costs**
   - **Improve Availability**
2. **Remote monitoring**
3. **Apply technology WT fleet-wide**

Pilot Effort - Technology Evaluations

Purpose

- Determine if advanced pattern recognition technology could be effectively applied to wind-turbine monitoring
- Find the optimal vendor

Approach

- Evaluate various vendors' offerings through simultaneous 3 month pilot efforts
- Evaluate: ease of use, application features, reliability, accuracy, deployment costs, and vendor support

Project Results

- Scientech's PdP was chosen for Wind fleet-wide deployment
- Also decided to deploy at all Coal sites

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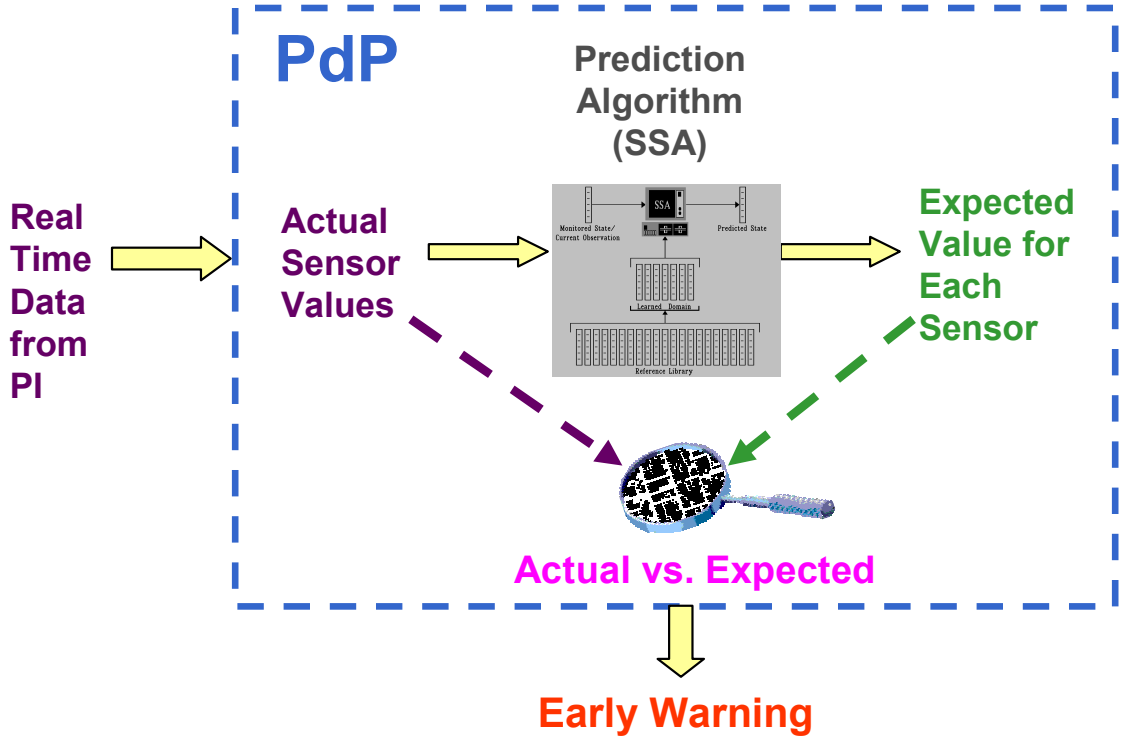
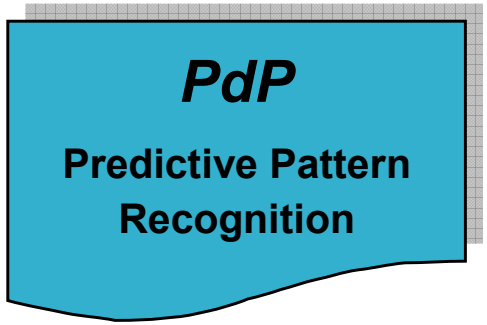
PdP – Predictive Pattern Recognition

- Utilizes a statistical state algorithm for analysis
- Compares current state to learned or referenced states based upon related historical information
- Used as a collective signal (component) monitoring tool for anomaly detection
- Can determine very subtle condition changes
- Model & signal status indications

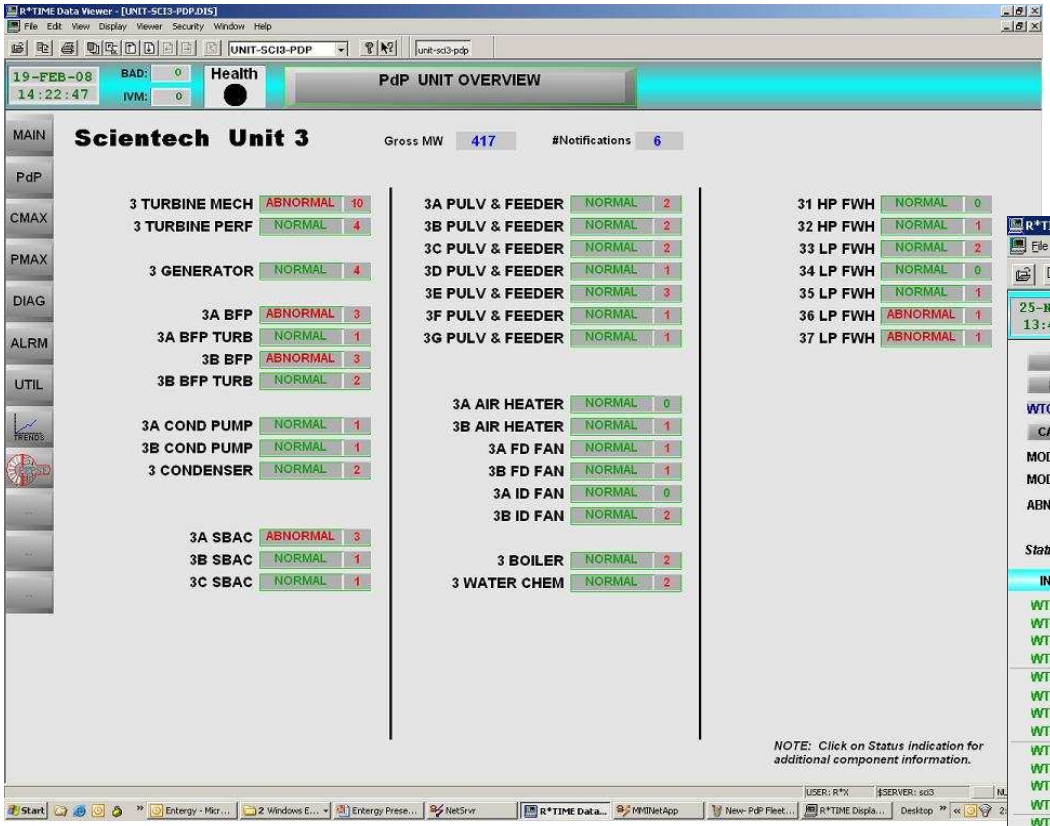


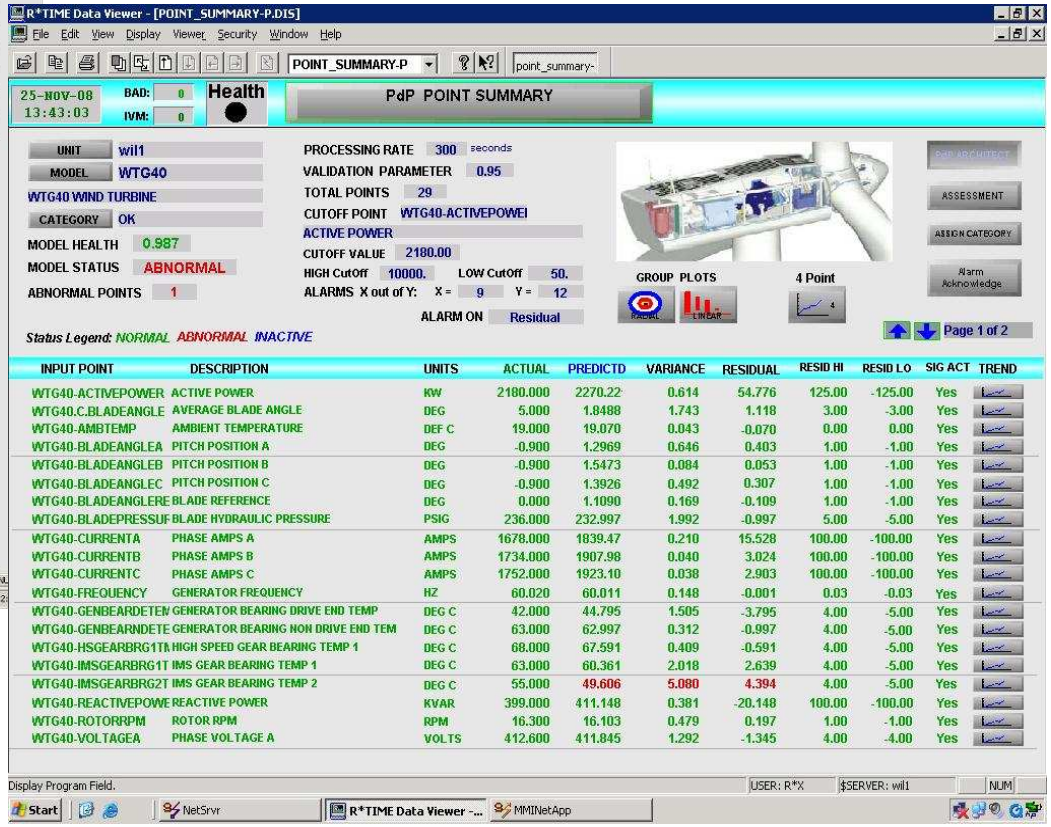
PdP - “Ins and Outs”



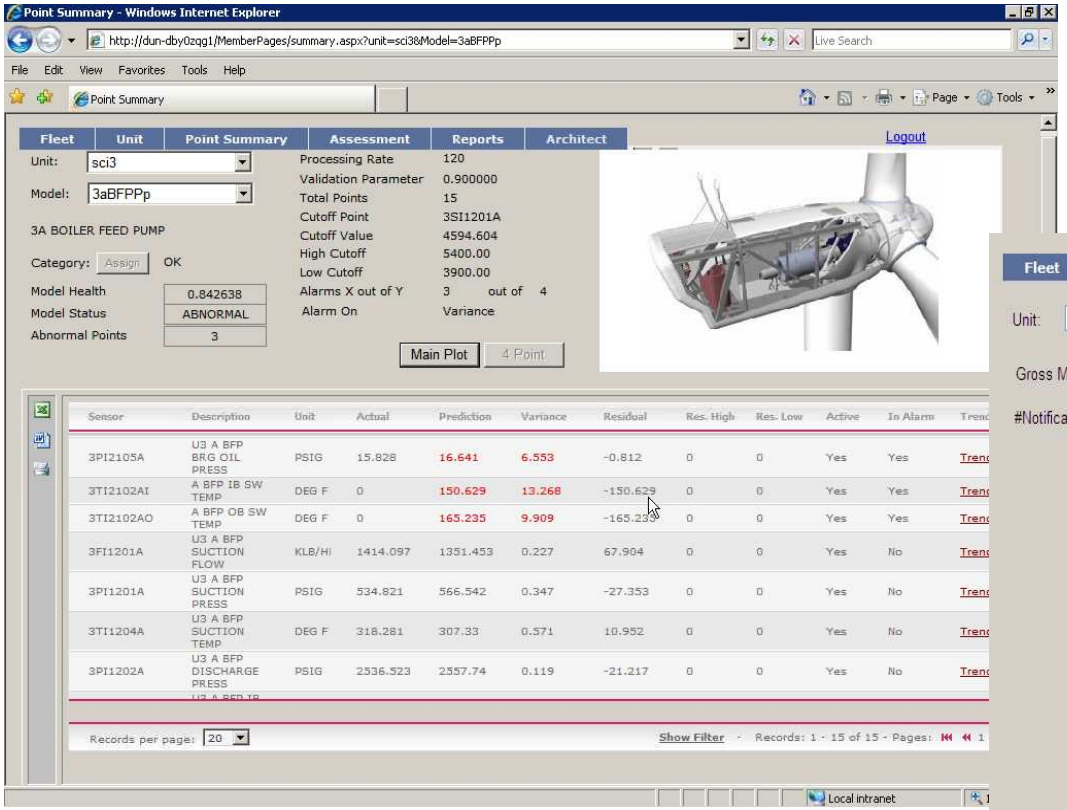
- Primary inputs:
  - Process data from PI
  - Other real-time data sources
- Outputs:
  - Normal / Abnormal status indicators
  - Data plots and drill down
  - Sensor integrity information
  - Various reports

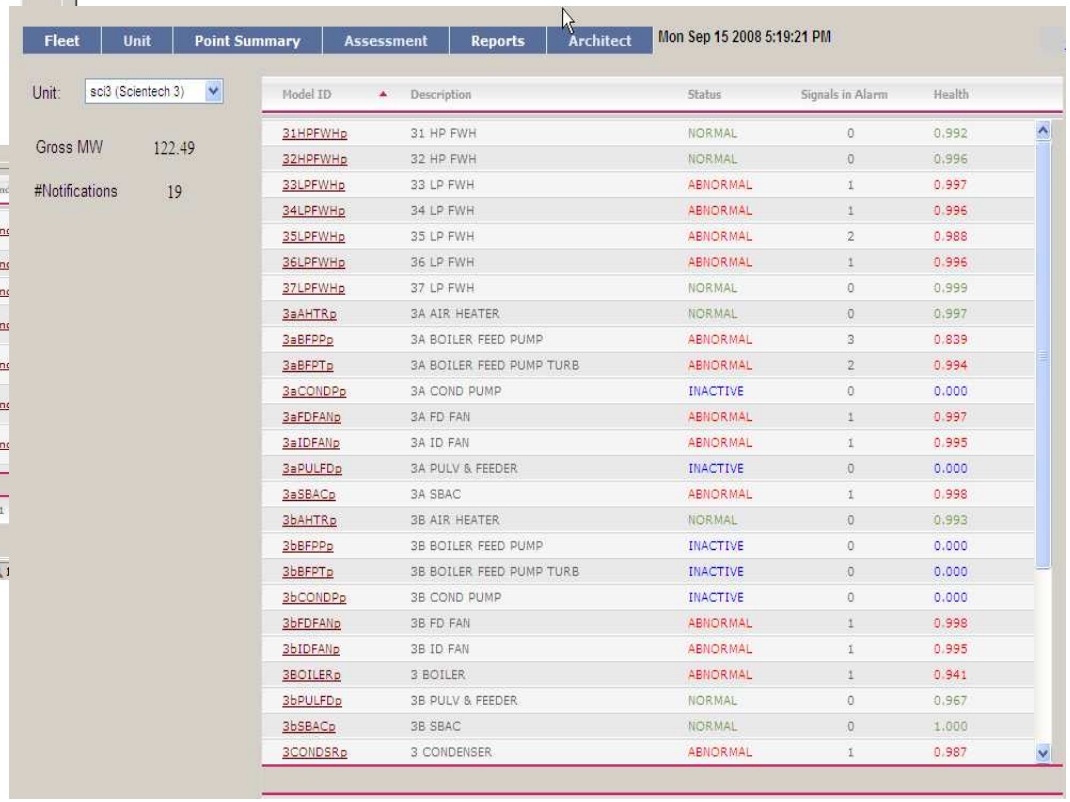
PdP - Displays



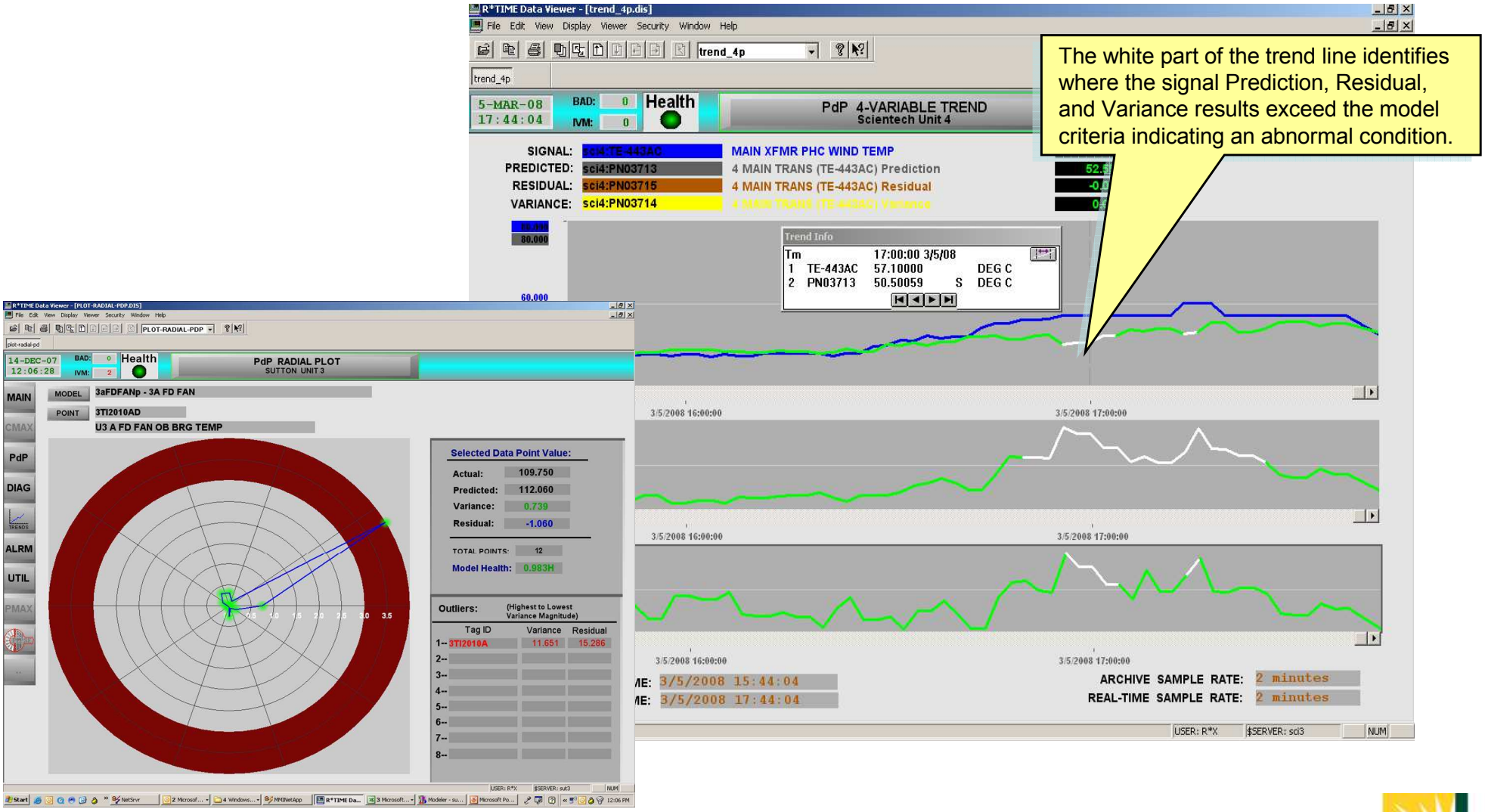


PdP - Web Displays



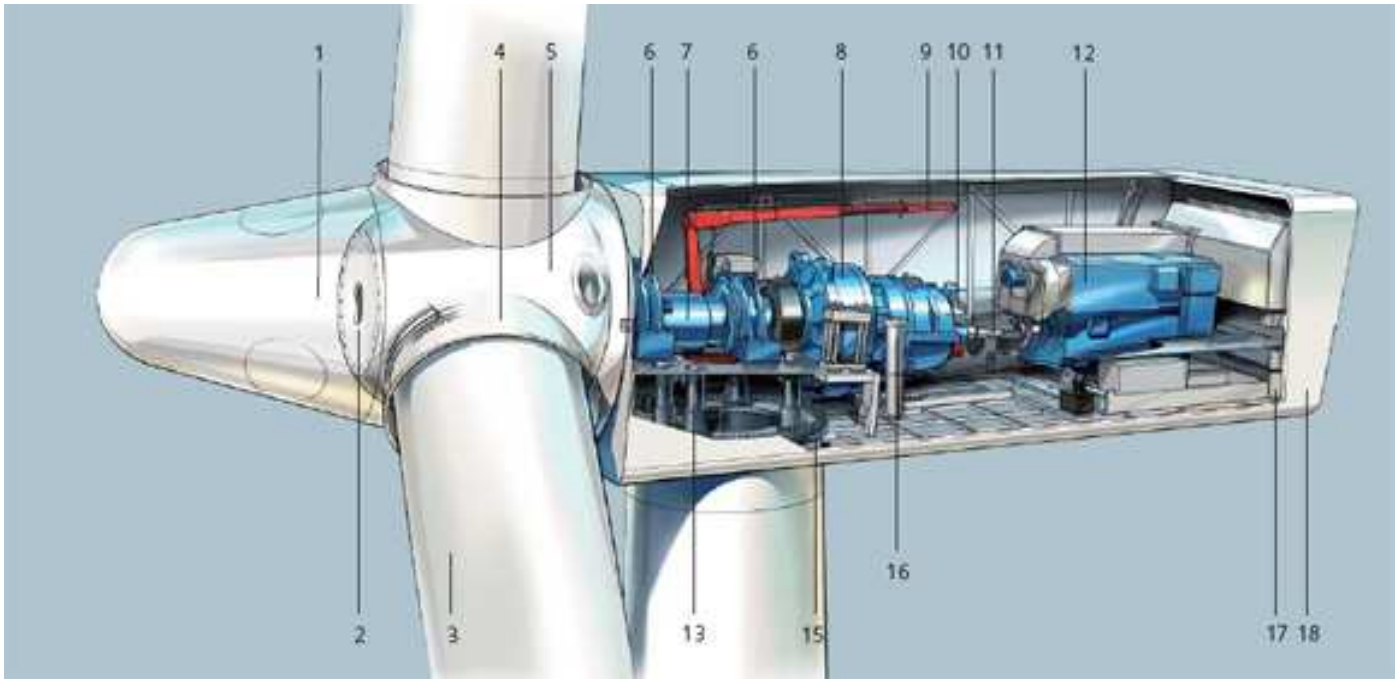


PdP - Result Views



The white part of the trend line identifies where the signal Prediction, Residual, and Variance results exceed the model criteria indicating an abnormal condition.

The Nacelle – What's inside the box



Ref: Siemens SWT36107 Wind Turbine

1 – Spinner
2 – Spinner Bracket
3 – Blade
4 – Pitch Bearing
5 – Rotor Hub
6 – Main Bearing
7 – Main Shaft
8 – Gear Box
9 – Service Crane
10 – Brake Disc
11 – Coupling
12 – Generator
13 – Yaw Gear
14 – Tower
15 – Yaw Ring
16 – Oil Filter
17 – Generator Fan
18 – Canopy / Nacelle

Typical Monitored Parameters

Critical Components

- Rotor
- Blades
- Pitch Mechanism
- Nacelle
- Gear Box
- Main Gear
- Generator
- Hydraulic System
- Yaw System

PITCH SYSTEM

- Pitch angle
- Current to blade pitch servomotor
- Pitch angle velocity
- Pitch angle set point
- Servo speed set point
- Servo motor temperature
- Status signal servo brake

TURBINE SYSTEM

- Rotor speed
- Electrical power
- Wind speed at met tower
- Wind speed wind turbine
- Wind direction at met tower
- Yaw alignment
- Air temperature

GENERATOR

- Stator Temperatures
- Stator Currents
- Bearing Temperatures
- Bearing Vibrations

MAIN BEARING & GEAR

- Bearing Temperature
- Bearing Vibration
- Gear Vibration

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MIDWEST GENERATION

Wind-Turbine (WT) Modeling Approach

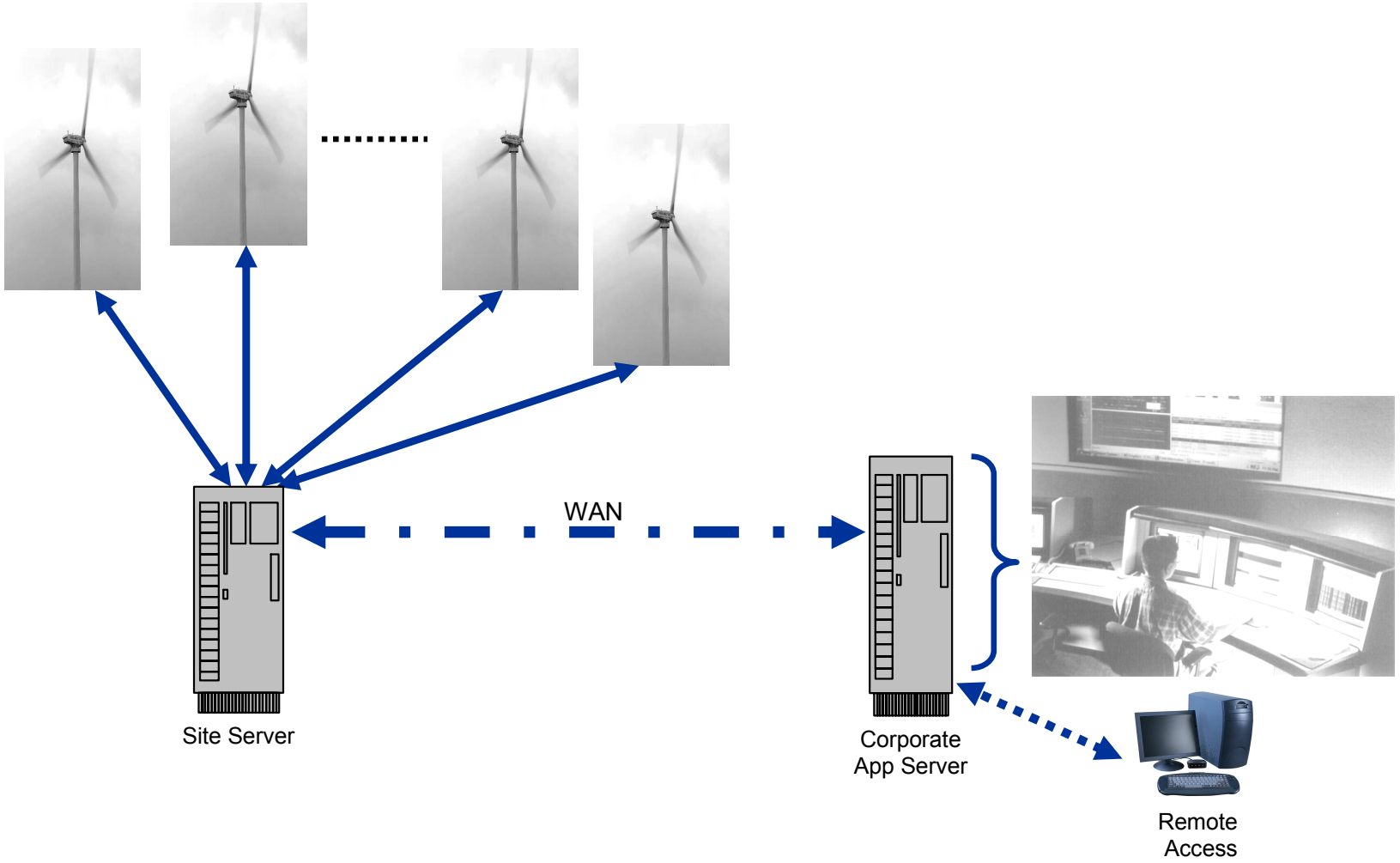
Model Configurations

- Presently configured one model type (generic) for all WTs
- Models are each comprised of 12-26 real-time sensor signals
- Models calculate bogey wind speed for comparison to actual
- PI utilizes this value to calculate a WTG efficiency

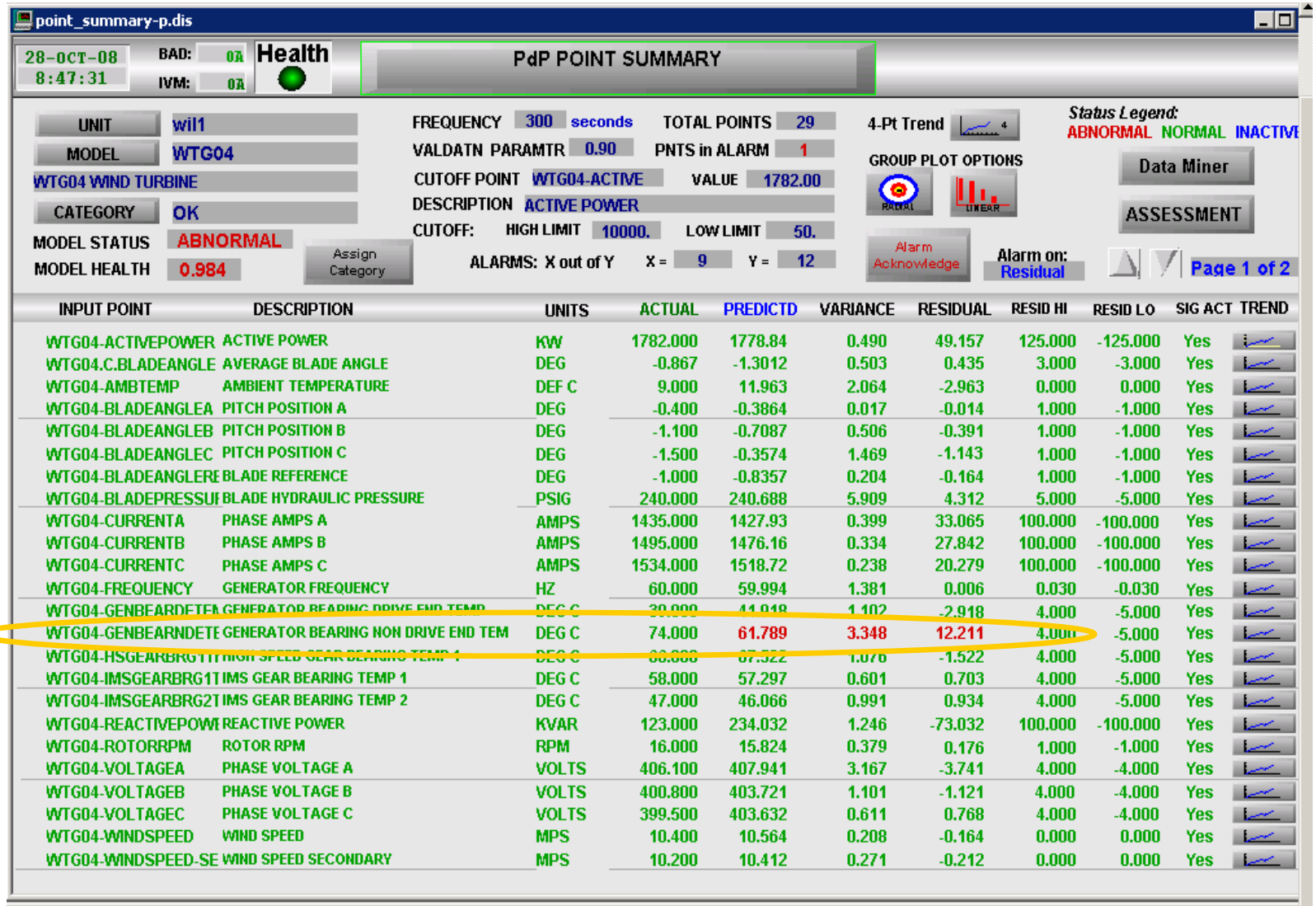
Monitoring

- PdP application server interfaced with common WT PI server
- Models processed every five minutes
- Results reported to responsible engineer and wind management persons
- Using web features for reporting findings
- PdP results exported to PI

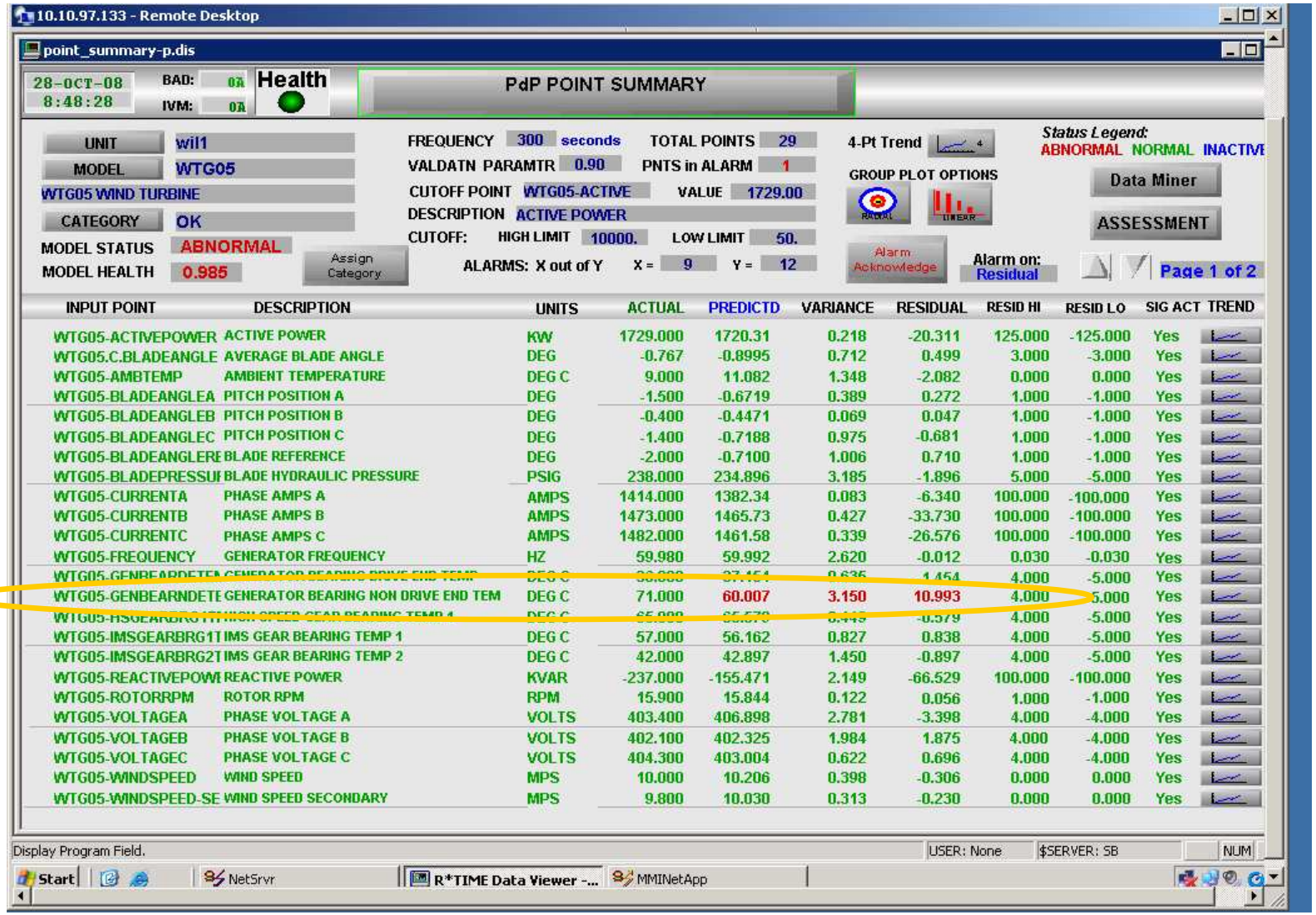
Application Deployment



Case Study - Generator NDE Bearing Temps Higher than predicted

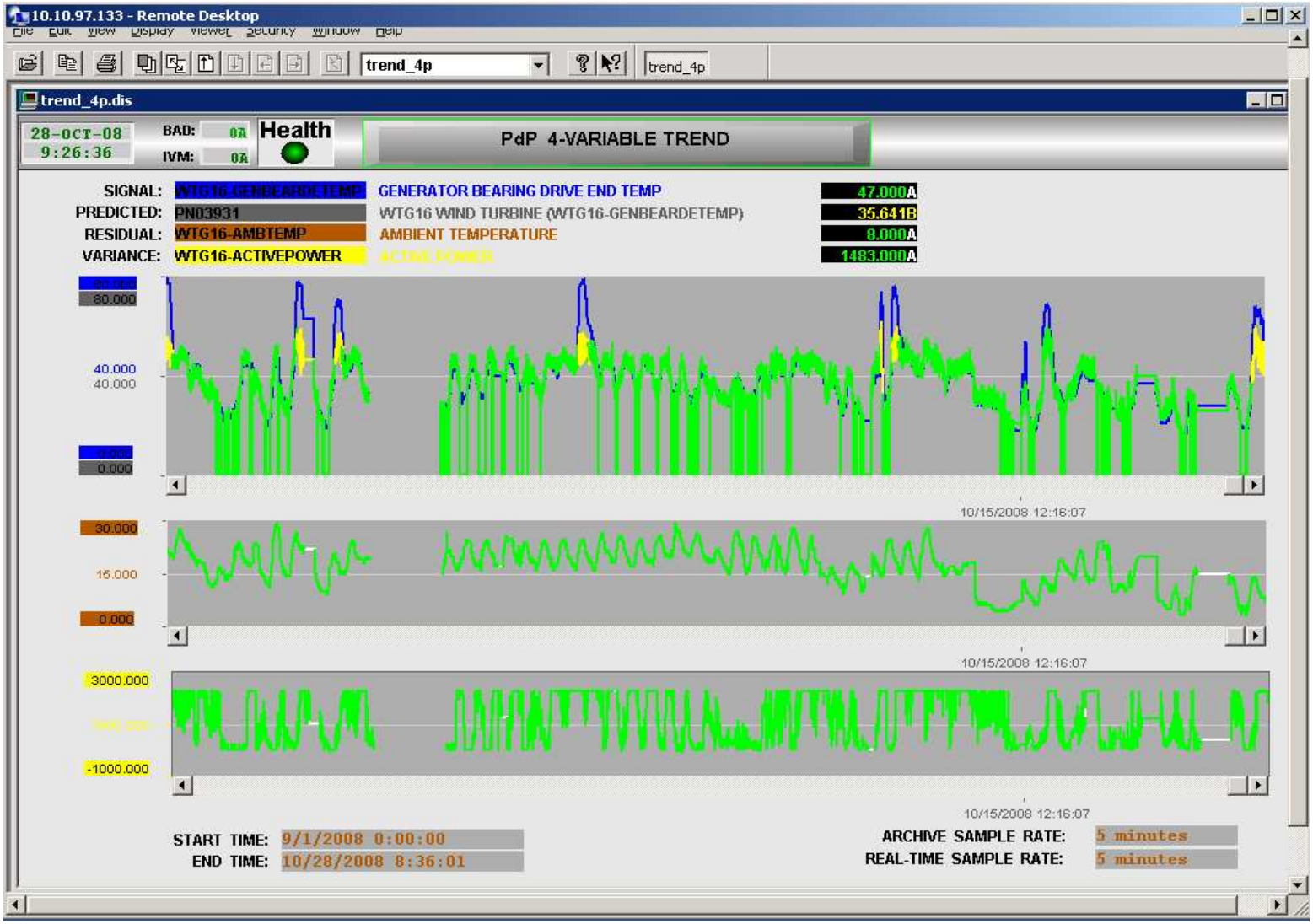


Another example of previous slide (this time WTG05)

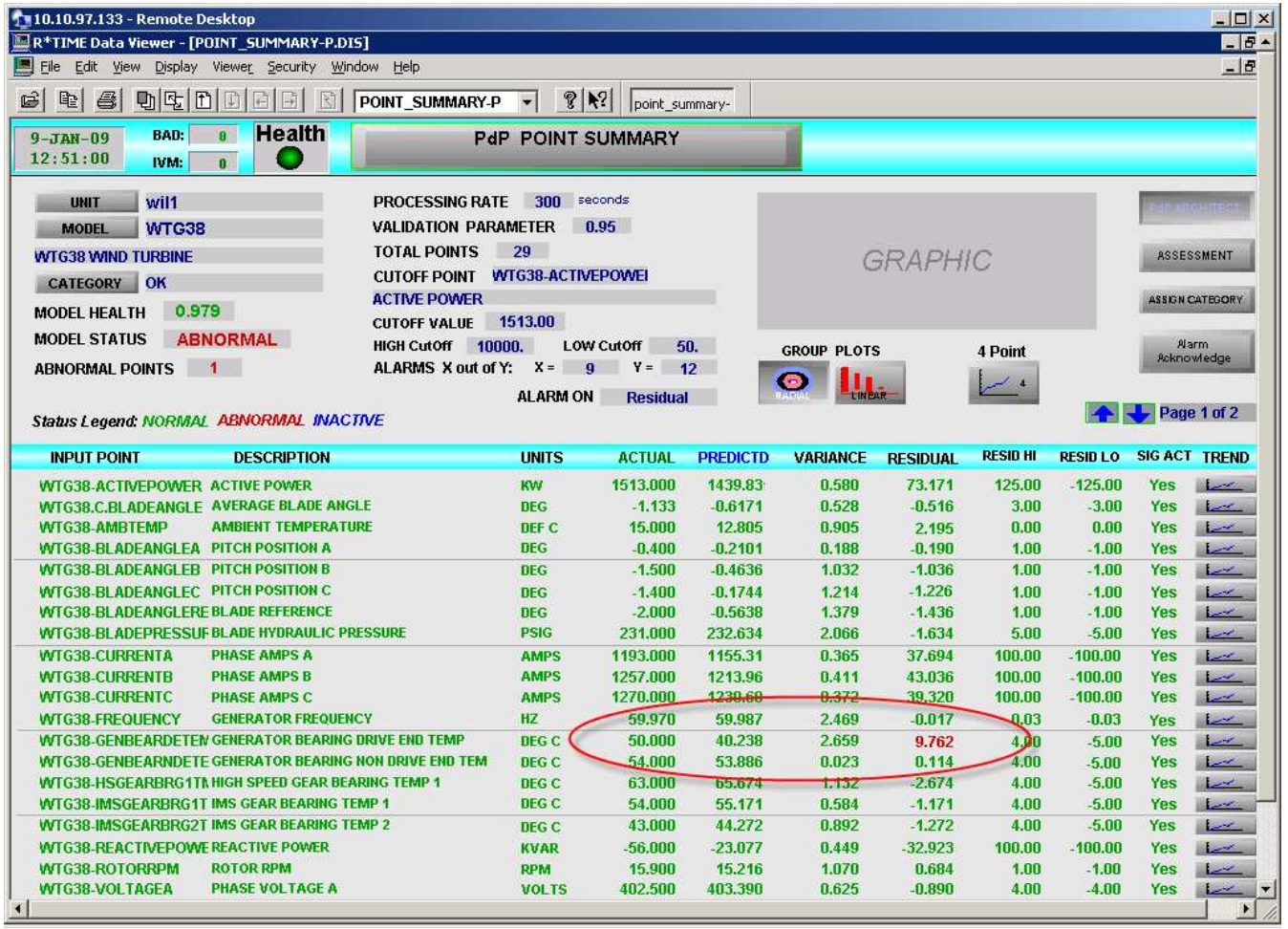


WTG16 Generator Bearing Drive End Temp

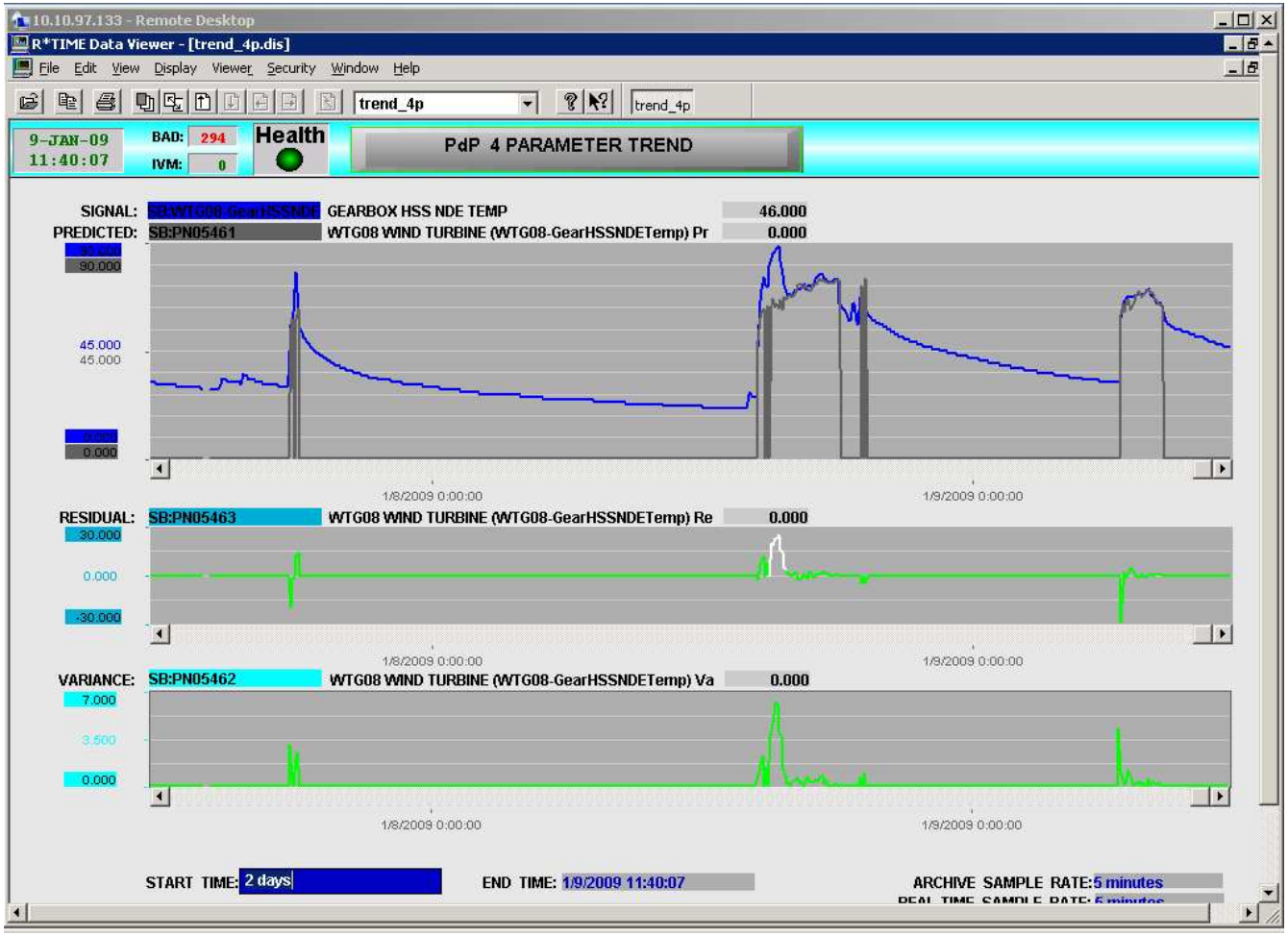
(Actual in Blue, Predicted in Green)



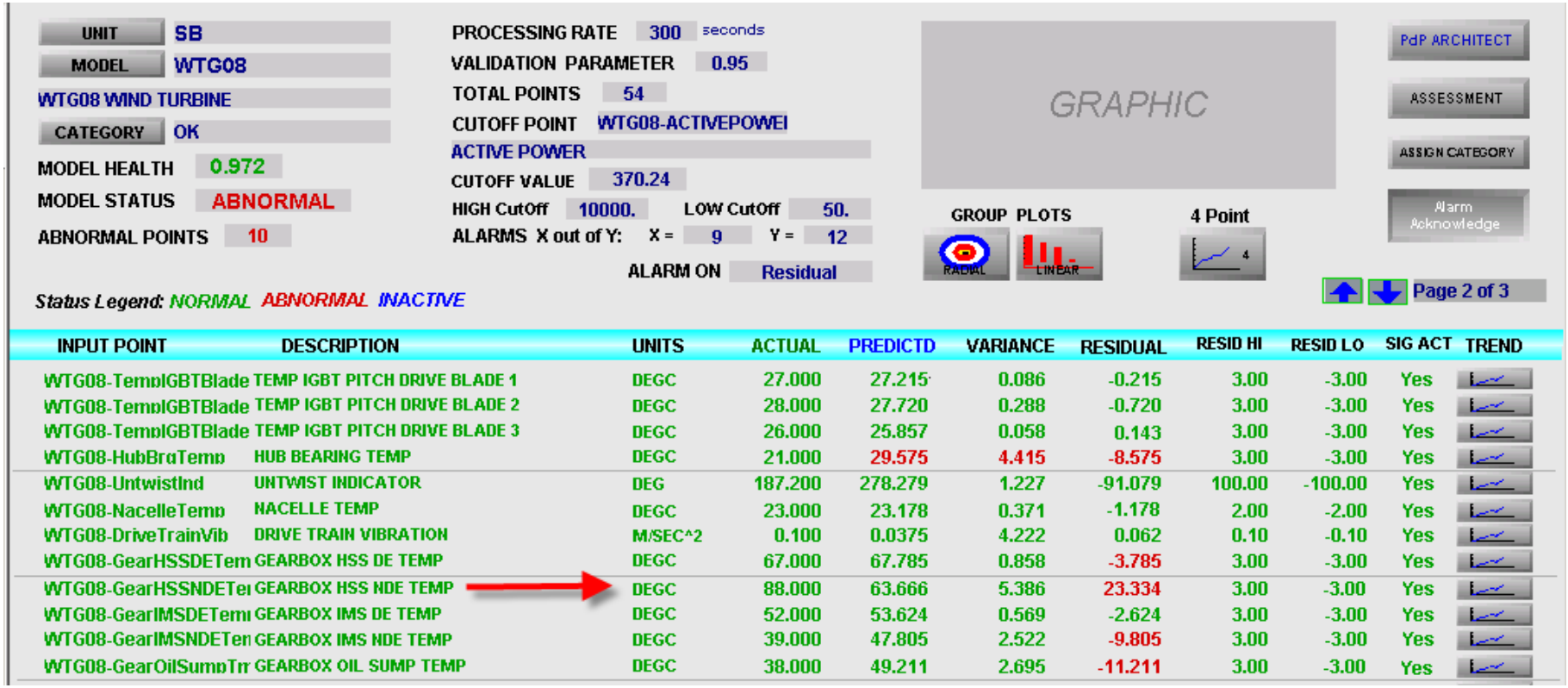
Gearbox High Speed Shaft Bearing Temp High



Gearbox High Speed Shaft – Actual vs Predicted



Another Gearbox Bearing Temp Spike



UNIT SB
MODEL WTG08
WTG08 WIND TURBINE
CATEGORY OK
MODEL HEALTH 0.972
MODEL STATUS ABNORMAL
ABNORMAL POINTS 10

PROCESSING RATE 300 seconds
VALIDATION PARAMETER 0.95
TOTAL POINTS 54
CUTOFF POINT WTG08-ACTIVEPOWEI
ACTIVE POWER
CUTOFF VALUE 370.24
HIGH CutOff 10000. LOW CutOff 50.
ALARMS X out of Y: X = 9 Y = 12
ALARM ON Residual

GRAPHIC

GROUP PLOTS RADIAL LINEAR
4 Point

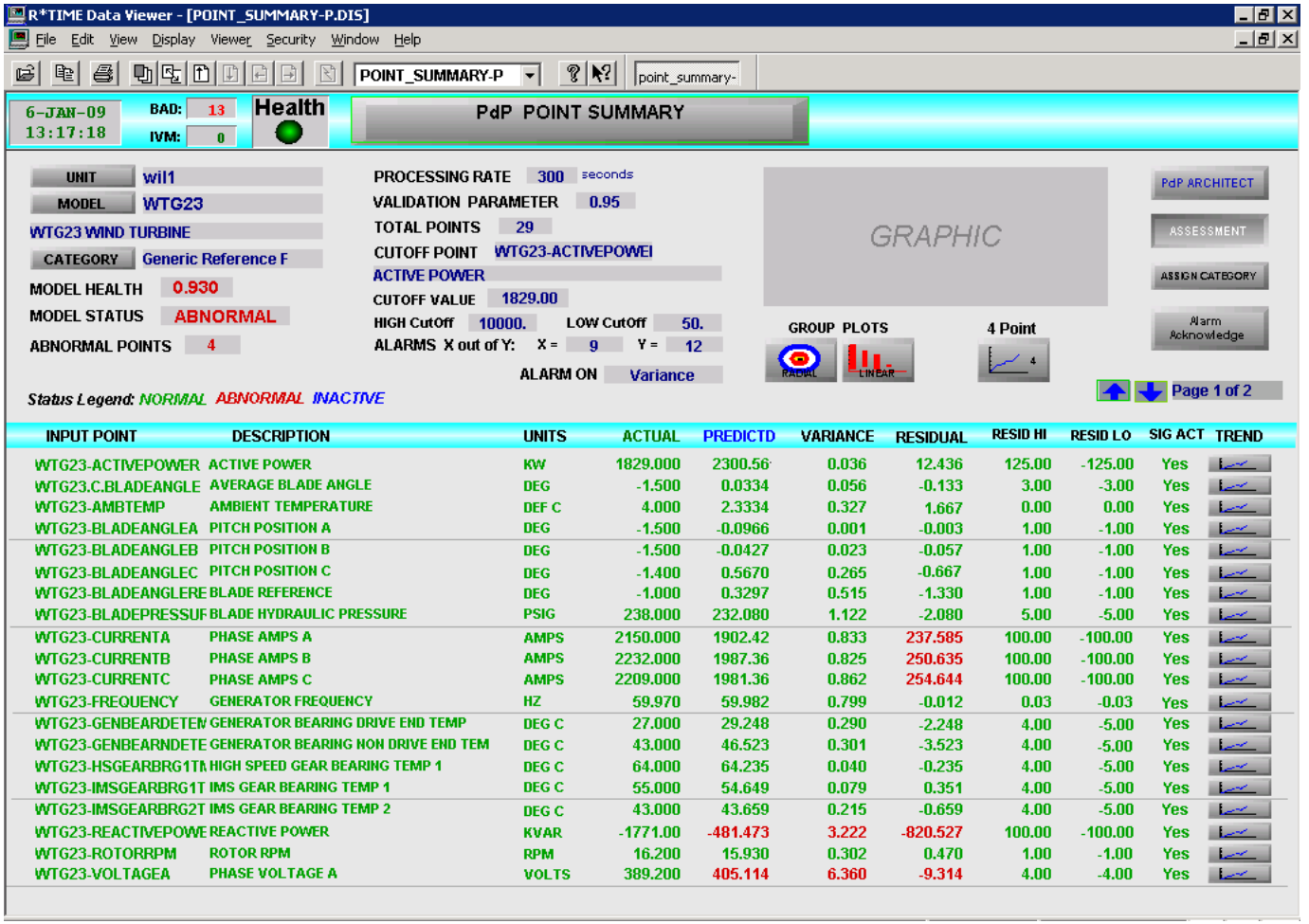
PdP ARCHITECT
ASSESSMENT
ASSIGN CATEGORY
Alarm Acknowledge

Page 2 of 3

Status Legend: NORMAL ABNORMAL INACTIVE

INPUT POINT	DESCRIPTION	UNITS	ACTUAL	PREDICTD	VARIANCE	RESIDUAL	RESID HI	RESID LO	SIG ACT	TREND
WTG08-TempIGBTBlade	TEMP IGBT PITCH DRIVE BLADE 1	DEGC	27.000	27.215	0.086	-0.215	3.00	-3.00	Yes	
WTG08-TempIGBTBlade	TEMP IGBT PITCH DRIVE BLADE 2	DEGC	28.000	27.720	0.288	-0.720	3.00	-3.00	Yes	
WTG08-TempIGBTBlade	TEMP IGBT PITCH DRIVE BLADE 3	DEGC	26.000	25.857	0.058	0.143	3.00	-3.00	Yes	
WTG08-HubBrgTemp	HUB BEARING TEMP	DEGC	21.000	29.575	4.415	-8.575	3.00	-3.00	Yes	
WTG08-UntwistInd	UNTWIST INDICATOR	DEG	187.200	278.279	1.227	-91.079	100.00	-100.00	Yes	
WTG08-NacelleTemp	NACELLE TEMP	DEGC	23.000	23.178	0.371	-1.178	2.00	-2.00	Yes	
WTG08-DriveTrainVib	DRIVE TRAIN VIBRATION	M/SEC^2	0.100	0.0375	4.222	0.062	0.10	-0.10	Yes	
WTG08-GearHSSDETem	GEARBOX HSS DE TEMP	DEGC	67.000	67.785	0.858	-3.785	3.00	-3.00	Yes	
WTG08-GearHSSNDETe	GEARBOX HSS NDE TEMP	DEGC	88.000	63.666	5.386	23.334	3.00	-3.00	Yes	
WTG08-GearIMSDETem	GEARBOX IMS DE TEMP	DEGC	52.000	53.624	0.569	-2.624	3.00	-3.00	Yes	
WTG08-GearIMSNDETe	GEARBOX IMS NDE TEMP	DEGC	39.000	47.805	2.522	-9.805	3.00	-3.00	Yes	
WTG08-GearOilSumpTr	GEARBOX OIL SUMP TEMP	DEGC	38.000	49.211	2.695	-11.211	3.00	-3.00	Yes	

Reactive Power Measurement - Issue



INPUT POINT	DESCRIPTION	UNITS	ACTUAL	PREDICTD	VARIANCE	RESIDUAL	RESID HI	RESID LO	SIG ACT	TREND
WTG23-ACTIVEPOWER	ACTIVE POWER	KW	1829.000	2300.56	0.036	12.436	125.00	-125.00	Yes	
WTG23.C.BLADEANGLE	AVERAGE BLADE ANGLE	DEG	-1.500	0.0334	0.056	-0.133	3.00	-3.00	Yes	
WTG23-AMBTEMP	AMBIENT TEMPERATURE	DEF C	4.000	2.3334	0.327	1.667	0.00	0.00	Yes	
WTG23-BLADEANGLEA	PITCH POSITION A	DEG	-1.500	-0.0966	0.001	-0.003	1.00	-1.00	Yes	
WTG23-BLADEANGLEB	PITCH POSITION B	DEG	-1.500	-0.0427	0.023	-0.057	1.00	-1.00	Yes	
WTG23-BLADEANGLEC	PITCH POSITION C	DEG	-1.400	0.5670	0.265	-0.667	1.00	-1.00	Yes	
WTG23-BLADEANGLERE	BLADE REFERENCE	DEG	-1.000	0.3297	0.515	-1.330	1.00	-1.00	Yes	
WTG23-BLADEPRESSUF	BLADE HYDRAULIC PRESSURE	PSIG	238.000	232.080	1.122	-2.080	5.00	-5.00	Yes	
WTG23-CURRENTA	PHASE AMPS A	AMPS	2150.000	1902.42	0.833	237.585	100.00	-100.00	Yes	
WTG23-CURRENTB	PHASE AMPS B	AMPS	2232.000	1987.36	0.825	250.635	100.00	-100.00	Yes	
WTG23-CURRENTC	PHASE AMPS C	AMPS	2209.000	1981.36	0.862	254.644	100.00	-100.00	Yes	
WTG23-FREQUENCY	GENERATOR FREQUENCY	HZ	59.970	59.982	0.799	-0.012	0.03	-0.03	Yes	
WTG23-GENBEARDETEN	GENERATOR BEARING DRIVE END TEMP	DEG C	27.000	29.248	0.290	-2.248	4.00	-5.00	Yes	
WTG23-GENBEARNDETE	GENERATOR BEARING NON DRIVE END TEM	DEG C	43.000	46.523	0.301	-3.523	4.00	-5.00	Yes	
WTG23-HSGEARBRG1TM	HIGH SPEED GEAR BEARING TEMP 1	DEG C	64.000	64.235	0.040	-0.235	4.00	-5.00	Yes	
WTG23-IMSGEARBRG1T	IMS GEAR BEARING TEMP 1	DEG C	55.000	54.649	0.079	0.351	4.00	-5.00	Yes	
WTG23-IMSGEARBRG2T	IMS GEAR BEARING TEMP 2	DEG C	43.000	43.659	0.215	-0.659	4.00	-5.00	Yes	
WTG23-REACTIVEPOWE	REACTIVE POWER	KVAR	-1771.00	-481.473	3.222	-820.527	100.00	-100.00	Yes	
WTG23-ROTORRPM	ROTOR RPM	RPM	16.200	15.930	0.302	0.470	1.00	-1.00	Yes	
WTG23-VOLTAGEA	PHASE VOLTAGE A	VOLTS	389.200	405.114	6.360	-9.314	4.00	-4.00	Yes	

Project Status

- ✓ **3 Wind-Farms are utilizing PdP Monitoring System, 6 more in deployment stages (to expand to 13 total wind-farm sites)**

- ✓ **235 Wind-Turbines being monitored by PdP**
  (to expand to >500 wind-turbines)

- ✓ **Expect to complete this summer**

- ✓ **Preliminary Findings; Some problems, Most sensor related.**

Coal Fleet Monitoring

- Modeling all Coal Units over 200 MW's
- 15 Units
- 254 Models
- Began in 11/08
- Lessons learned already
- Issues Identified
- Plan to complete modeling by March

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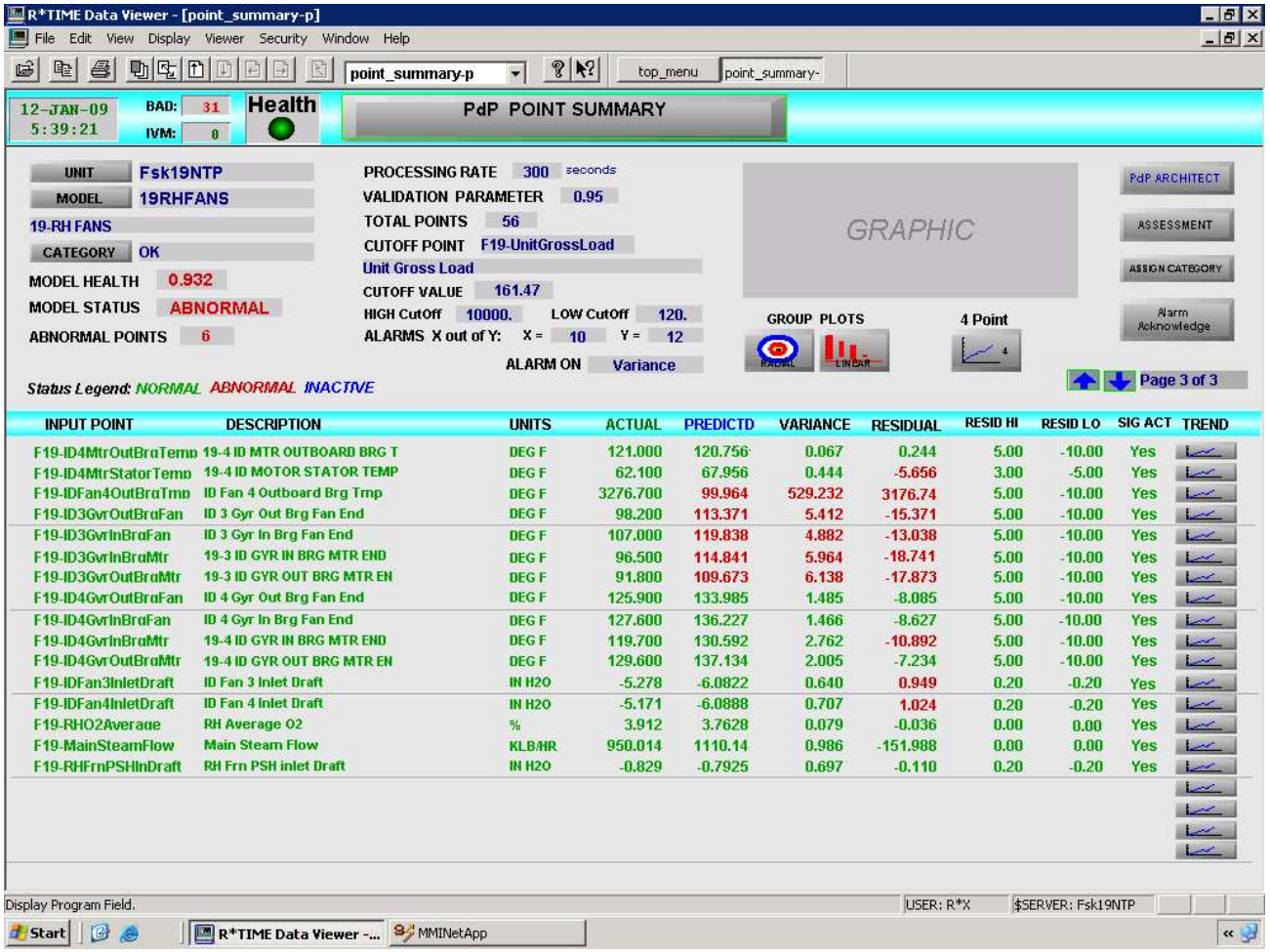
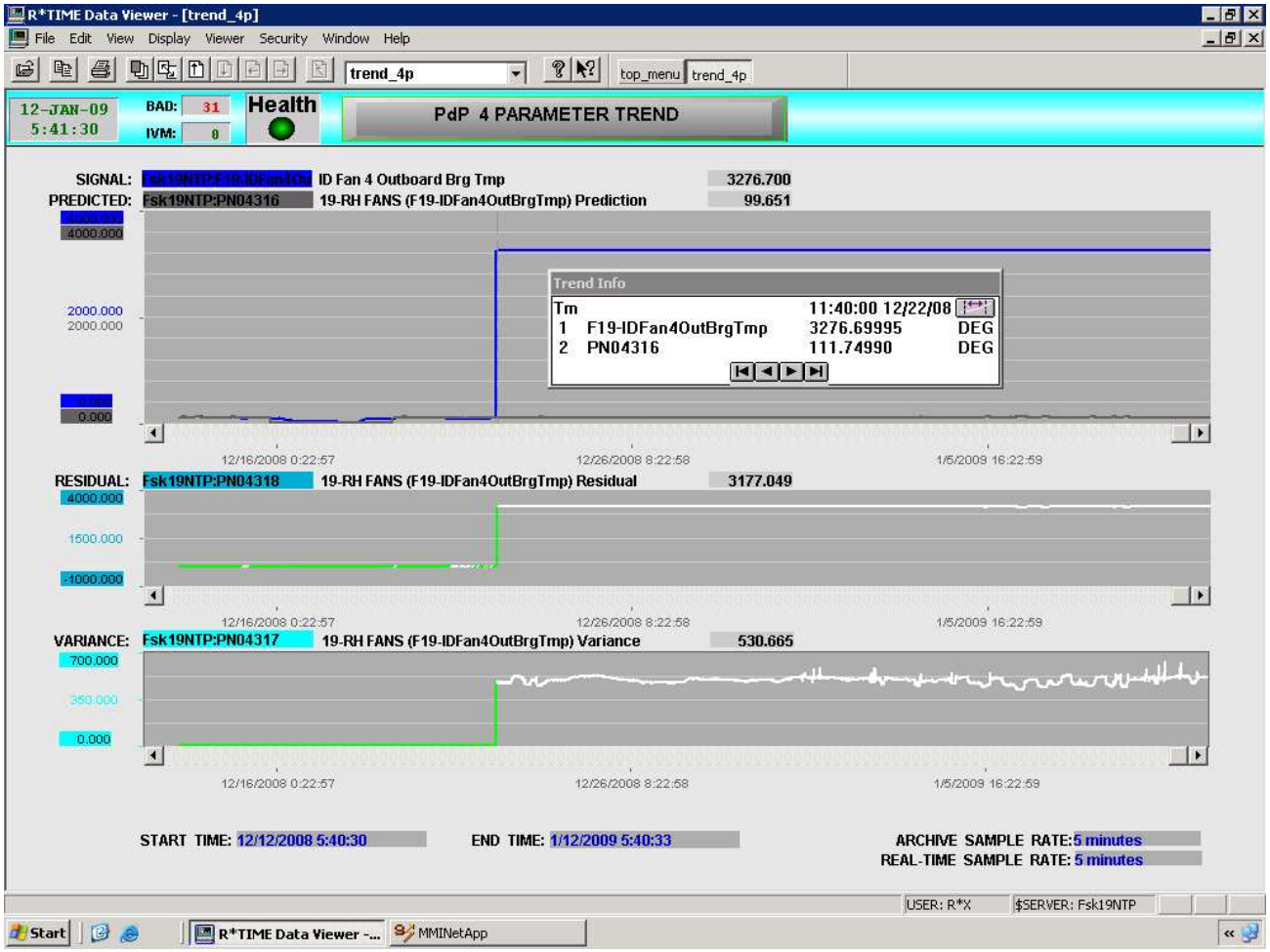
MIDWEST GENERATION

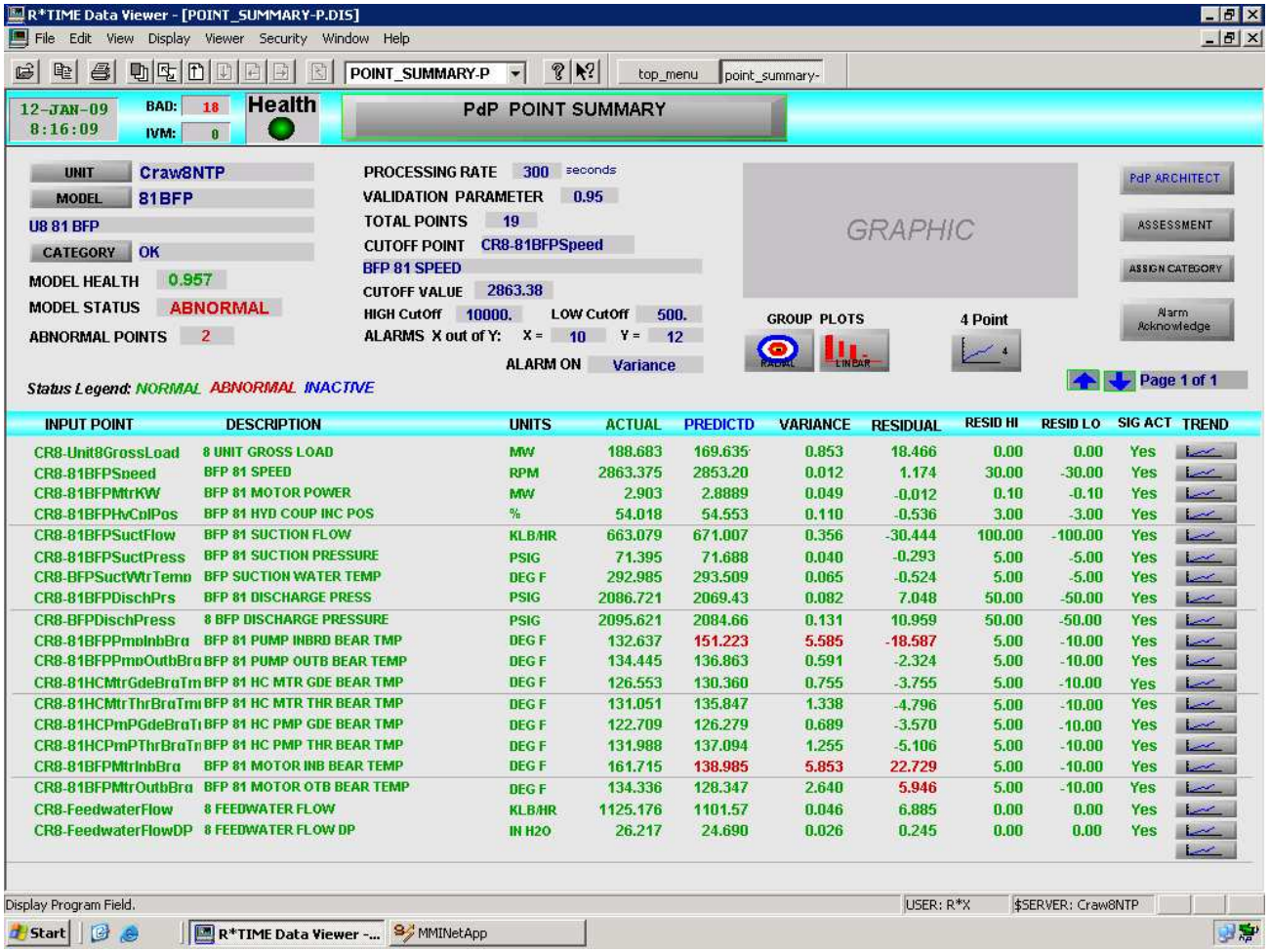
Coal Unit – ID Fan Thermocouple Failure



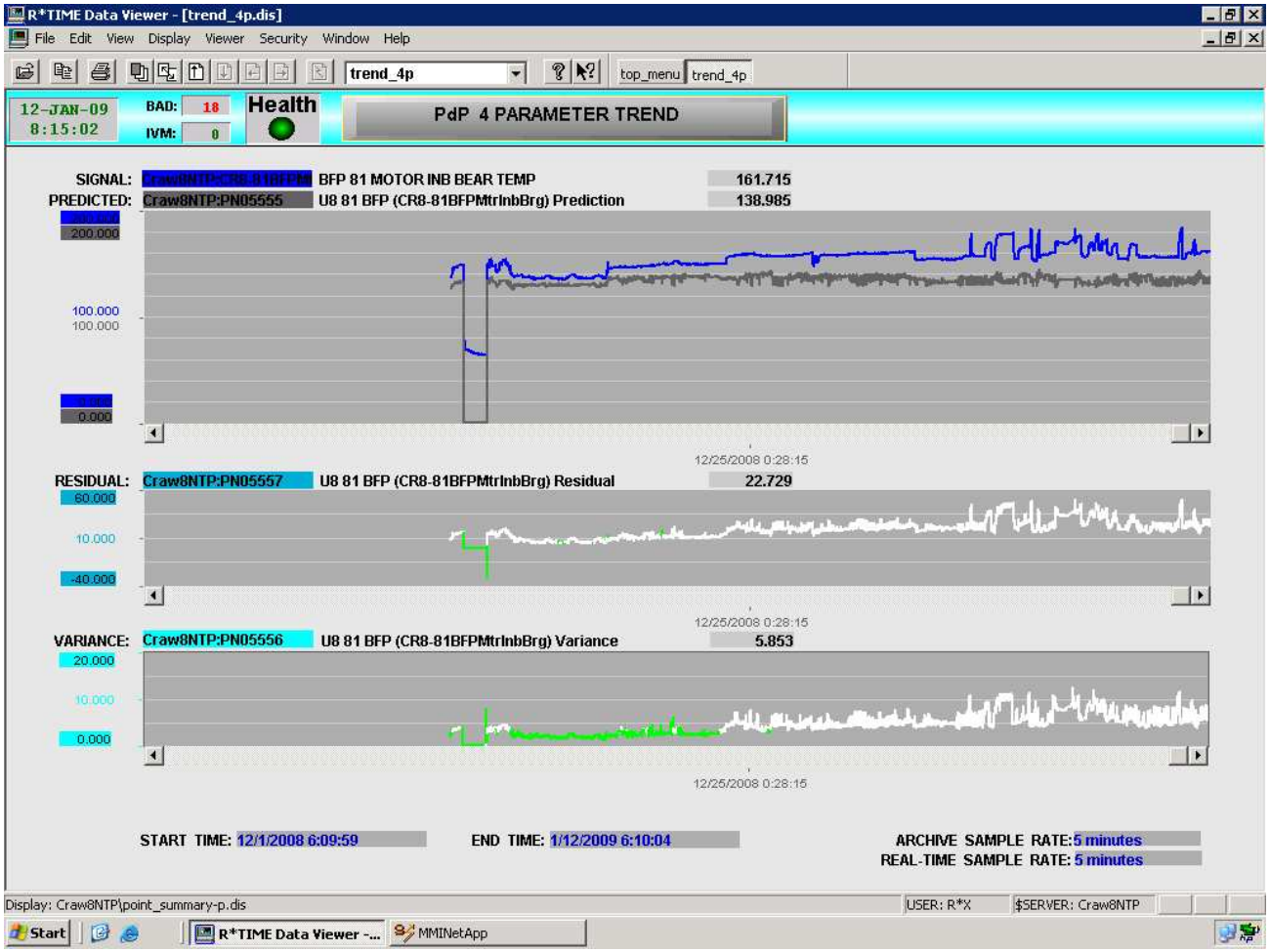
ID Fan Thermocouple – Actual vs Predicted



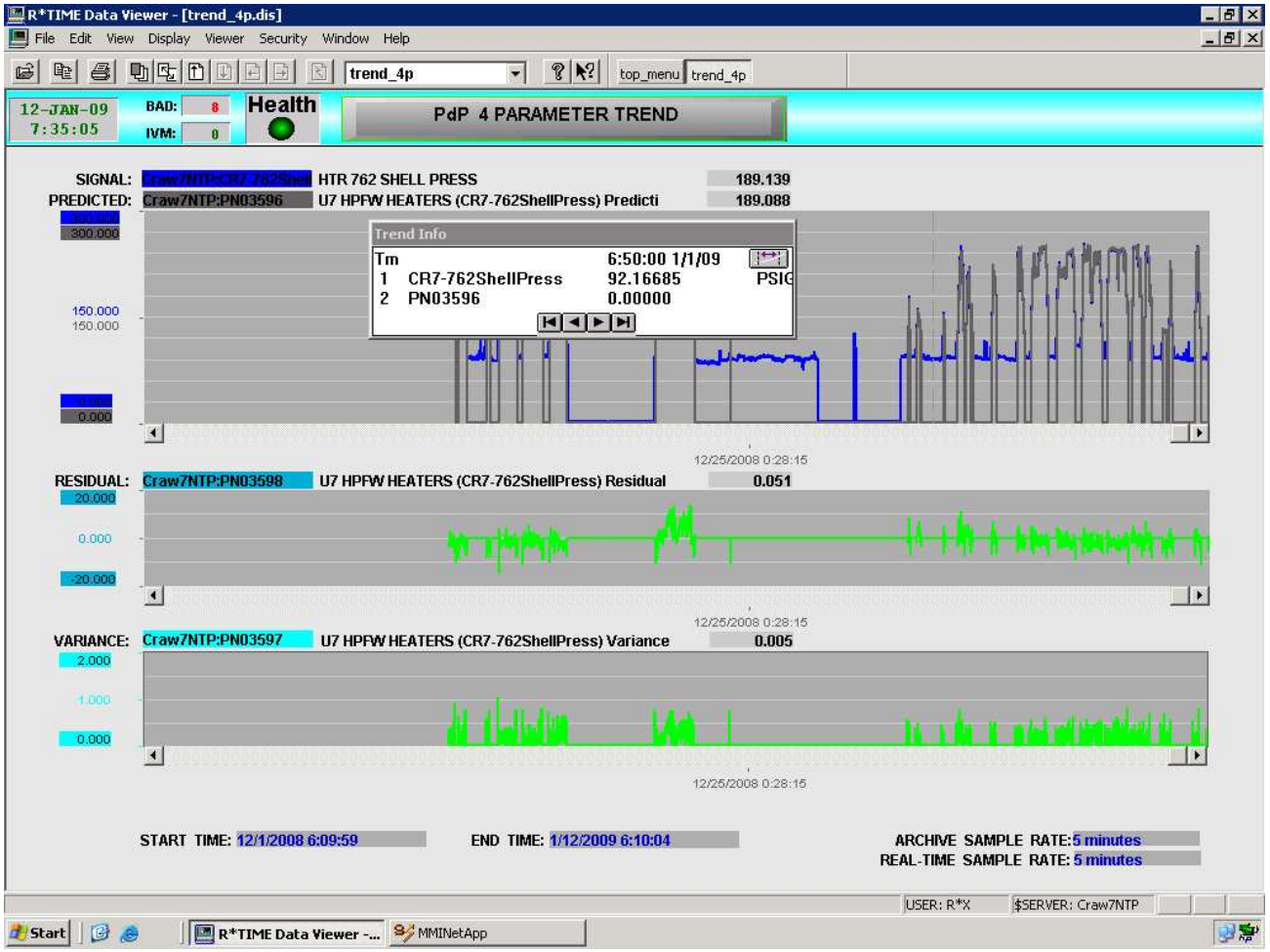
Coal Unit Boiler feed Pump Bearing Temp



Coal Unit Boiler Feed Pump
Inboard Bearing Temperature - High



Coal Unit Feedwater Heater Shell Pressure
"Lesson learned" : Include entire load range in Model



Questions ?