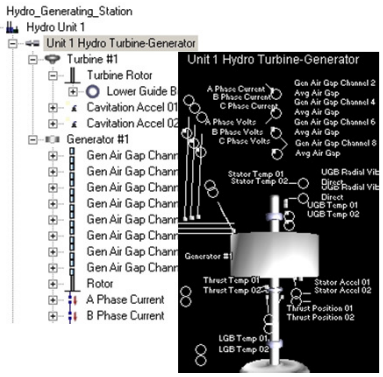
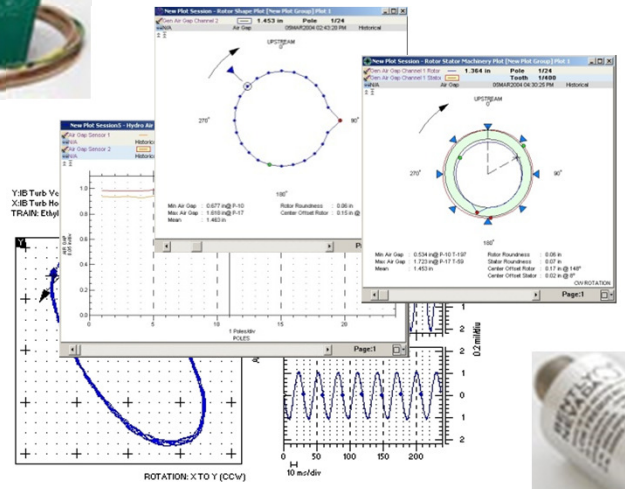


Protection, Management, and Optimization for Hydro-Power Assets and Operations

Bently Nevada



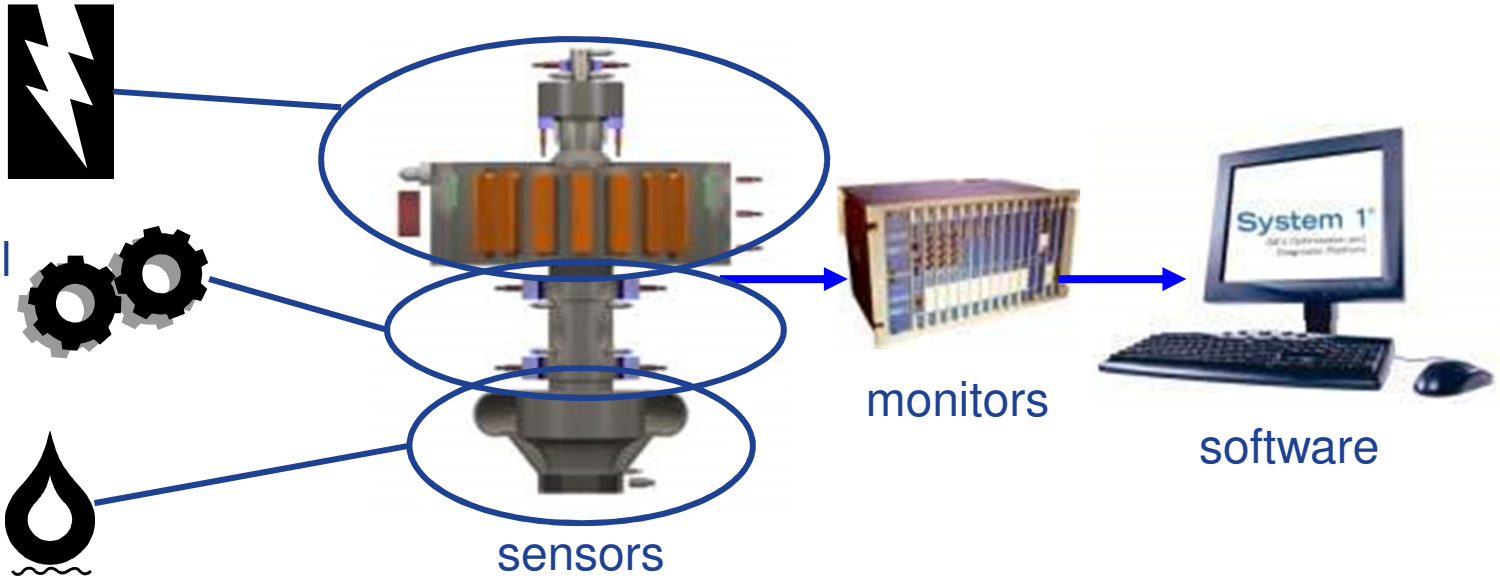
Common Malfunctions

Machinery Problem Categories

Hydro Turbine Generator problems fall into three main categories:

- Electrical
- Mechanical
- Hydraulic

Problems can be detected with condition monitoring systems and corrective action can be taken before the situation worsens.



List of malfunctions

Failure Modes and Detection

Generators

Faults

- Insulation Breakdown/Failure
- Rotor Pole Faults
- Bearing Faults
- Cooling System Faults
- Excitation Fault
- Rotor Stator Misalignment/Contact

Detection

- Temperature/Partial Discharge
- Magnetic Flux and Temperature
- Vibration signature and temperature
- Temperature and process data
- Voltage/Current Monitoring
- Generator Air Gap

Failure Modes & Detection

Turbines

Faults

- Erosion/Material Loss
- Unbalance
- Bearing Failures
- Hydraulic Faults
- Misalignment

Detection

•Relative and Seismic Vibration

•1x Vibration

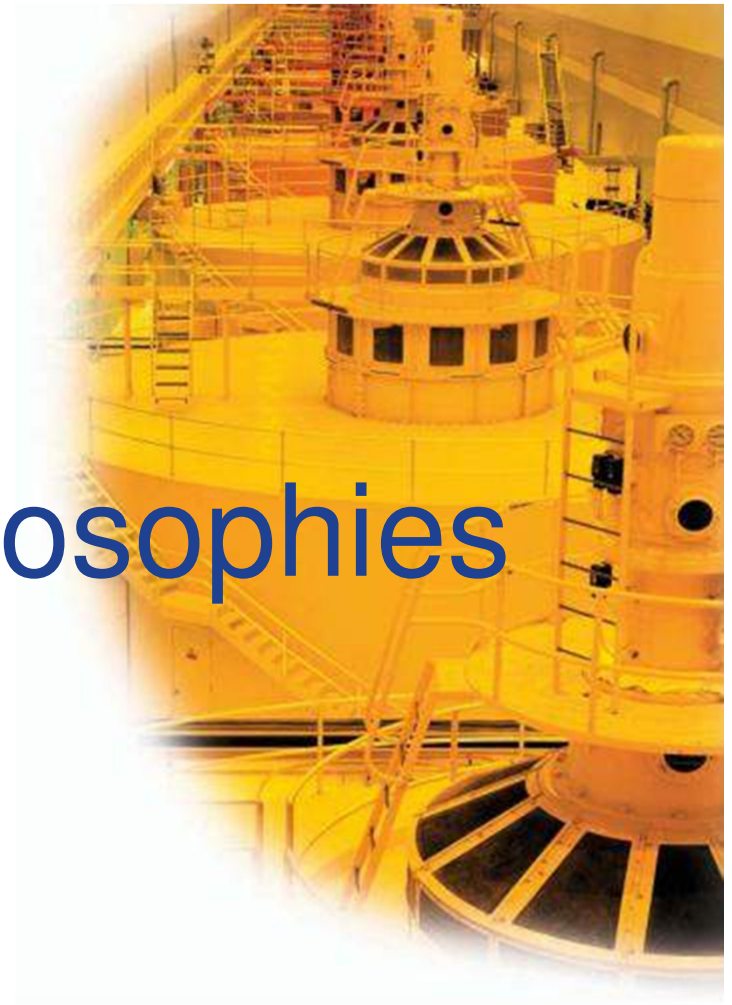
•Vibration signature and temperature

•Seismic and bearing vibration

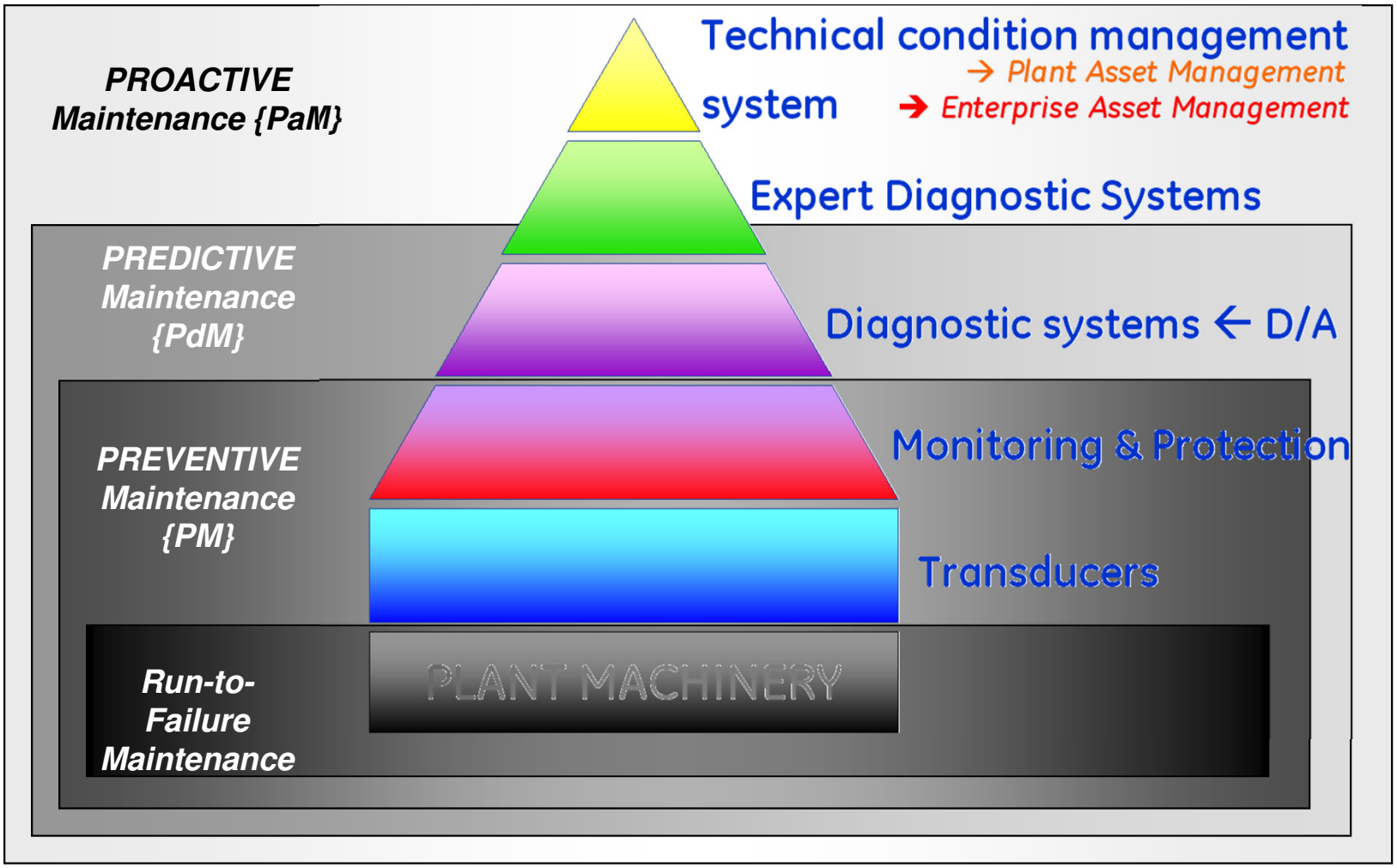
•1x and possibly 2x vibration changes. Orbit shape changes

•Correlate Process Data

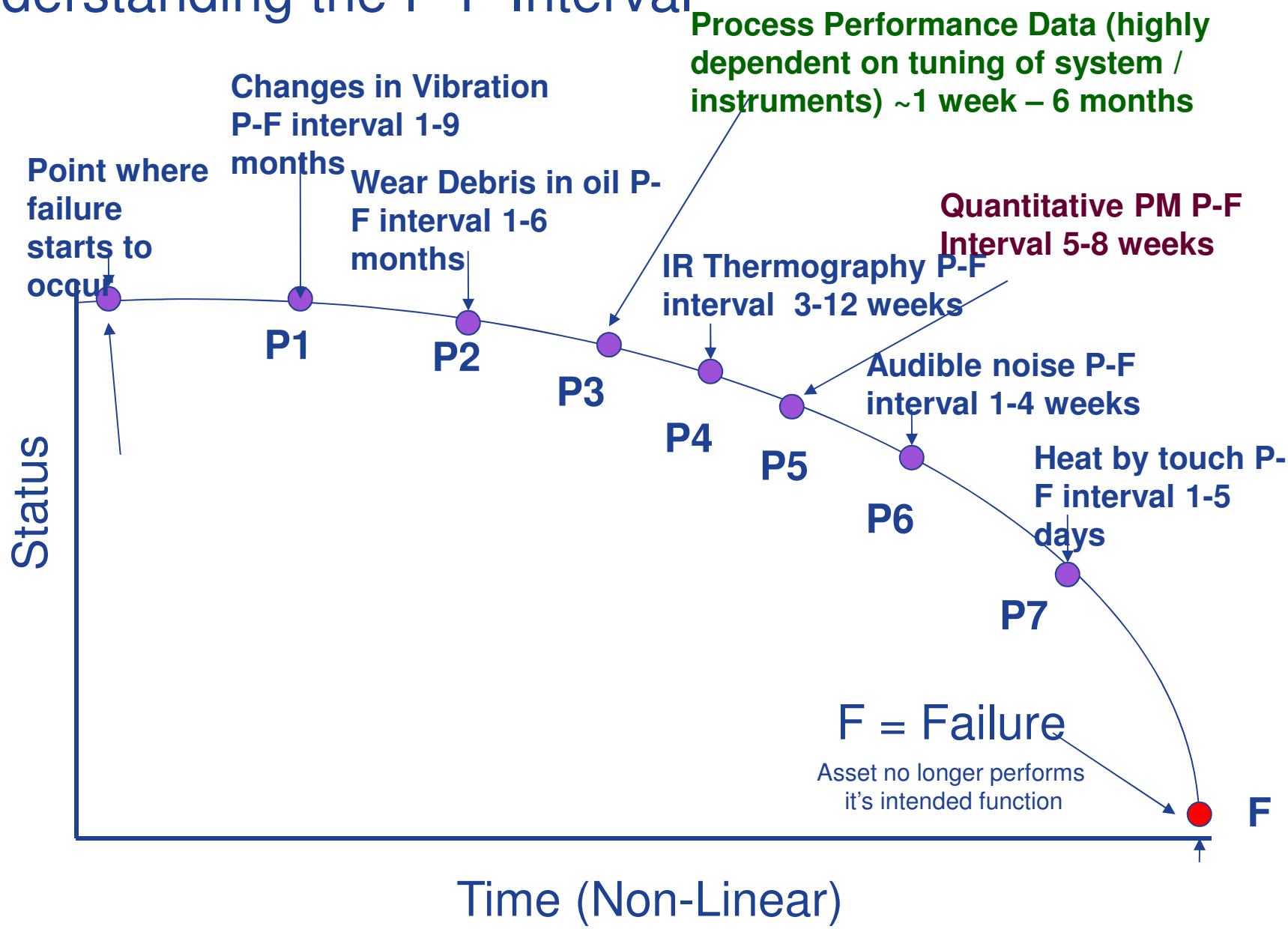
Maintenance Philosophies



MAINTENANCE STRATEGIES

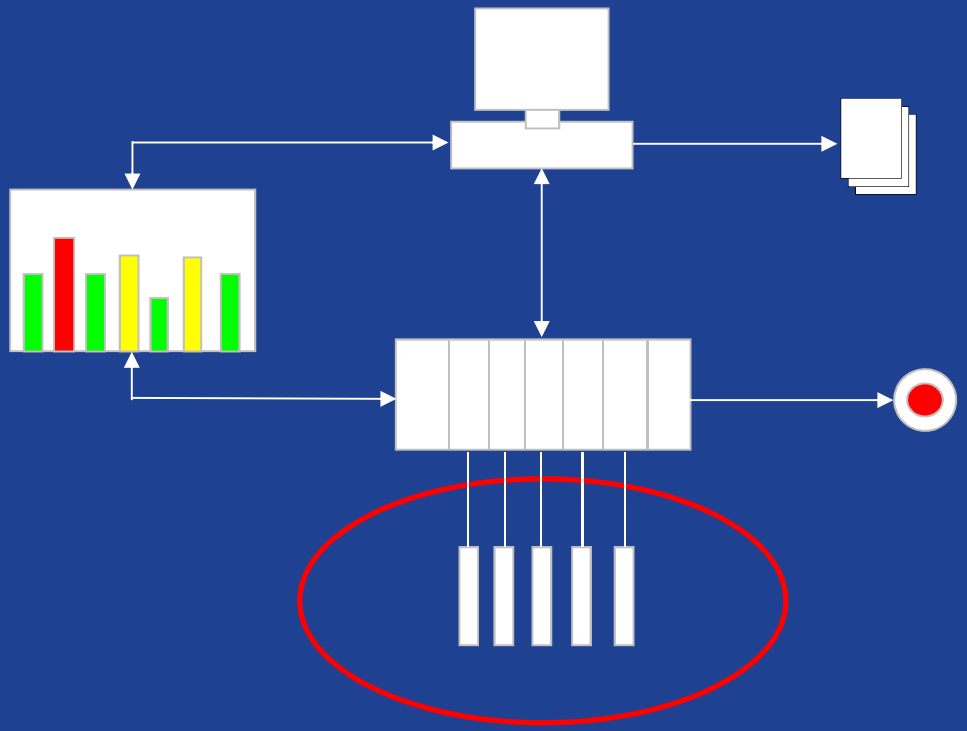


Understanding the P-F Interval



Hydro Condition Monitoring

The “Big Picture” Transducers



imagination at work

Proximity transducer system

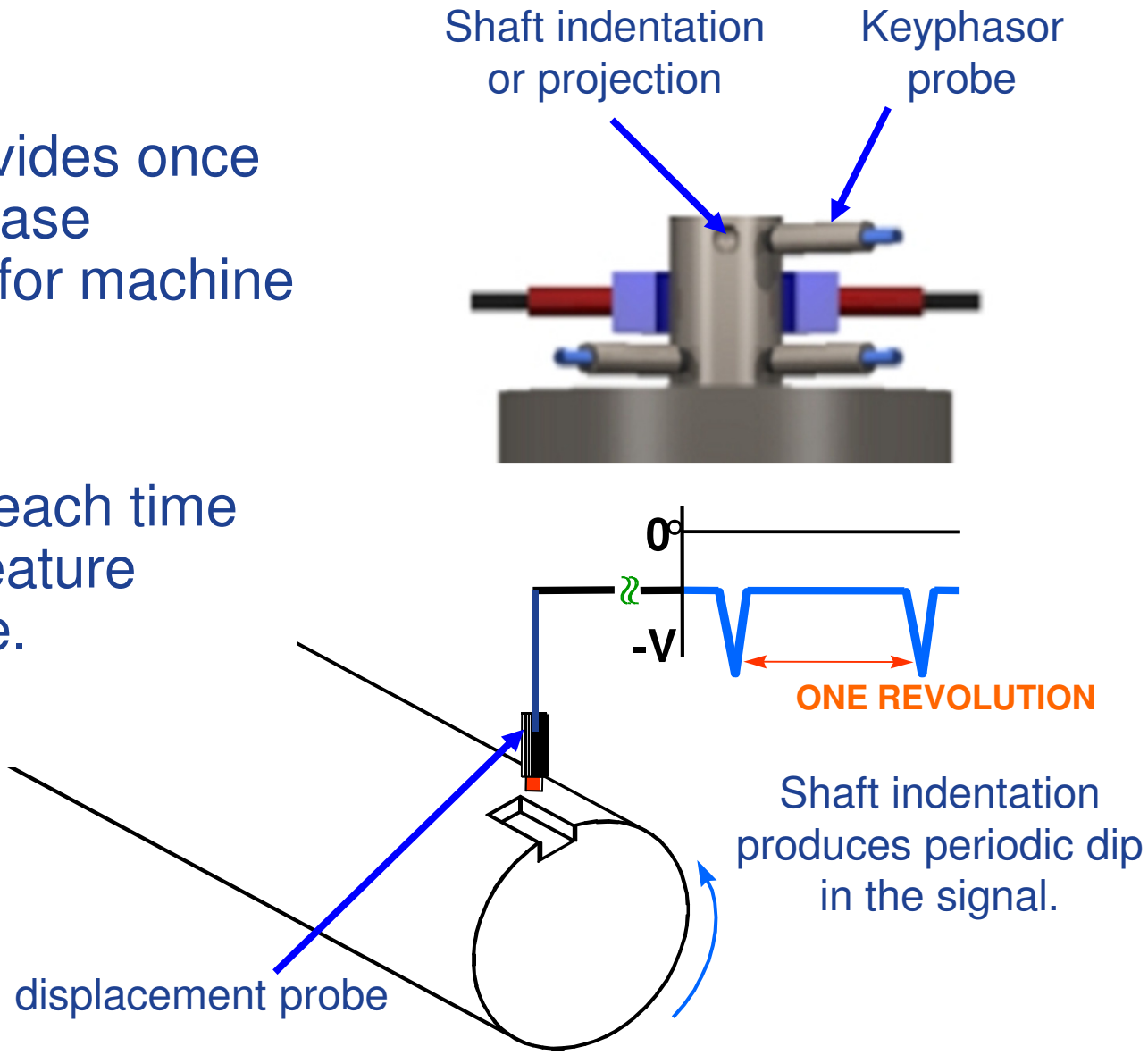
- **Radial vibration**
- **Thrust**
- **Keyphasor®**
- **Seal ring clearance**
- **Turbine blade clearance**

(submersible versions available)

Rotor Phase

- Keyphasor® provides once per revolution phase reference signal for machine rotor.

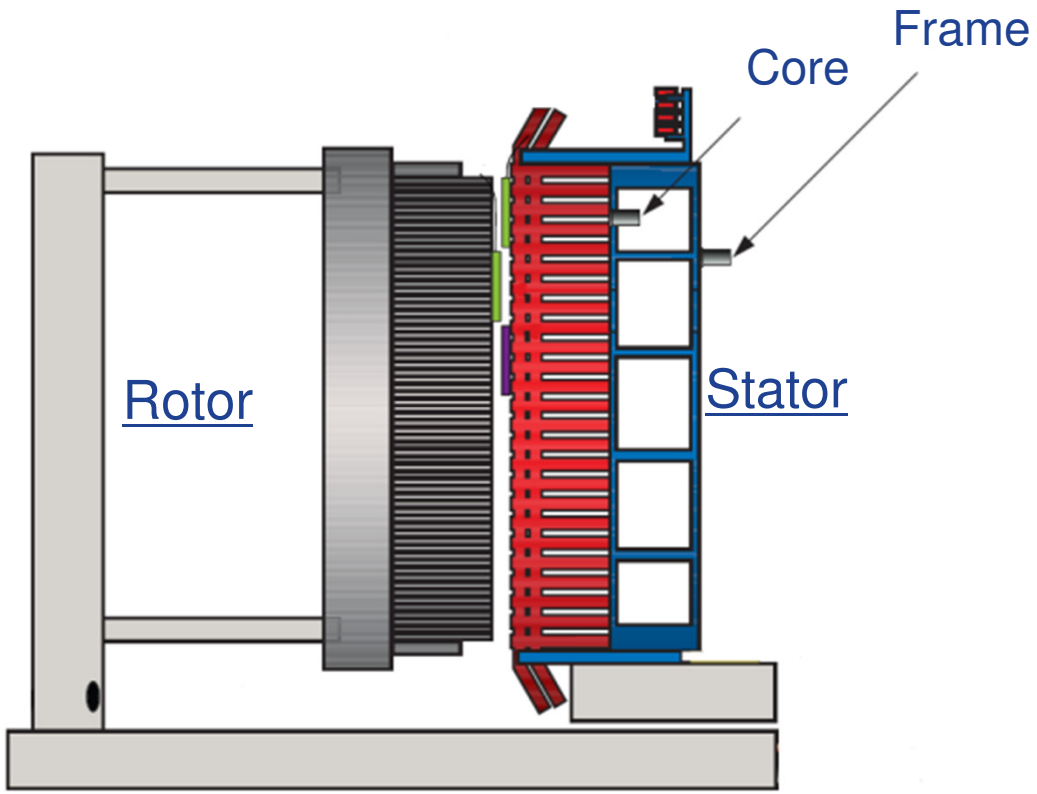
- Creates a pulse each time an appropriate feature passes the probe.



Low frequency velocity sensor for Hydro applications

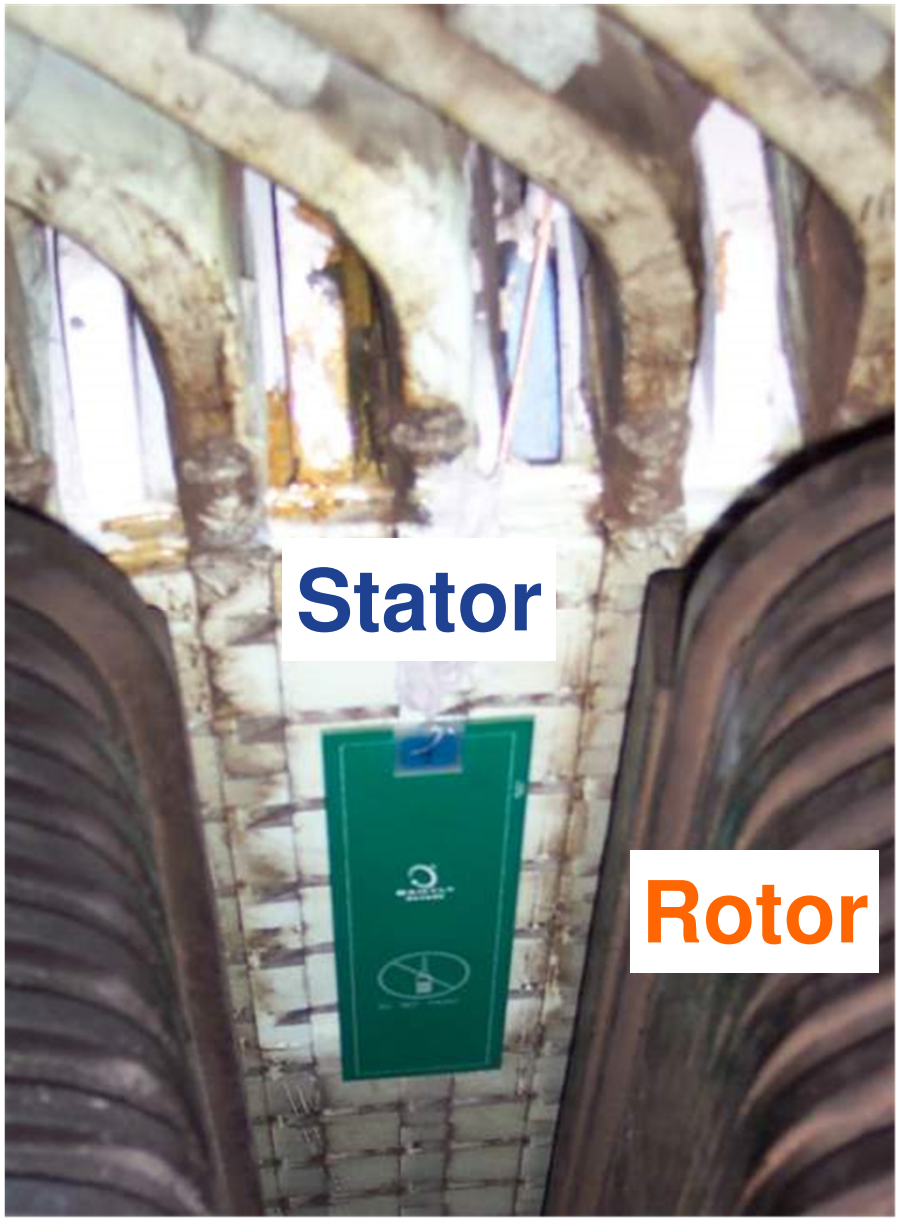
- Bearing housing vibration
- 0.5 - 1000 Hz sensitivity
- Low signal-to-noise ratio
- Moving coil technology

Stator Frame / Stator Core Vibration

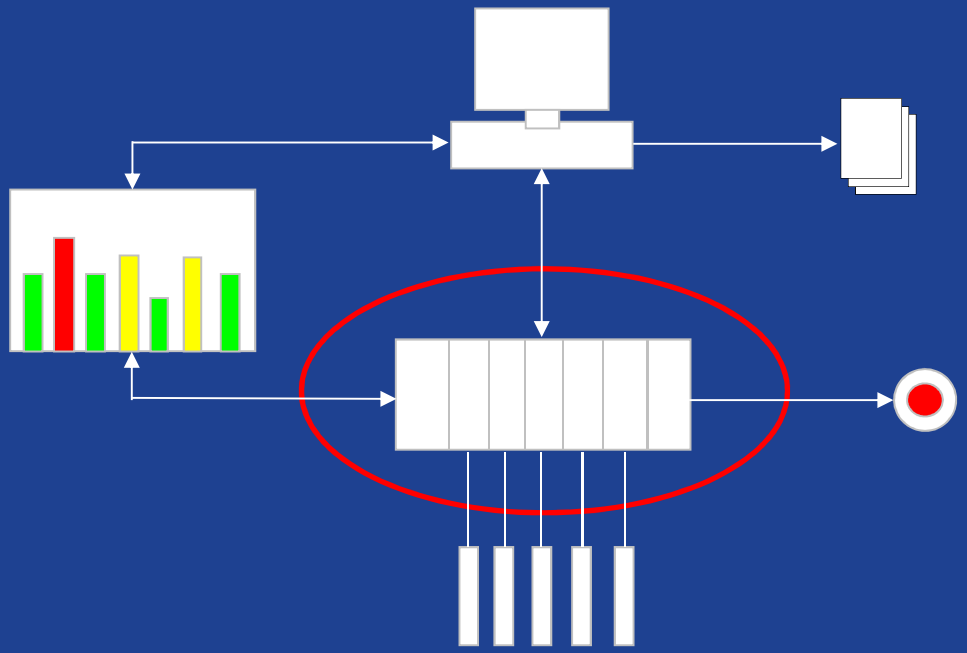


Air gap sensors

- Stator to Rotor Air gap
- Two Ranges
- 50 mm – range 1800 mils (45.7 mm)
- 20 mm – range 720 mils (18.3 mm)



Protection



Bently Nevada 3500 System

- Continuous On-line Monitoring and Protection
- Modbus Interface to SCADA and DCS
- 4 Vibration / Position Inputs Per Monitor – up to 56 channels
- 6 or 16 Channel Temperature Monitors
- Rotor Phase (Keyphasor)
- Direct Interface to System 1
- Display Options
  - LCD (backlit available)
  - VGA touchscreen
  - PC-based display

Instrument Rack with bulkhead mount option

3500/46M Hydro Monitor

- Proximity probes
  - *Direct, Gap, 1X, Not 1X, NX*
- Air Gap
  - *Avg., Min., Max gap and pole number*
- Velocity
  - *Direct, 1X, 2X*
- Embedded Shear Pin Failure Detection More
- Multimode Capability
  - *Eight configurable machine states*
  - *Distinct alarm set points and time delays*
  - *Multimode can be based on Speed, Load, Direction of Rotation, Environmental Conditions, Process Variable Levels etc.*
  - *Feeds state-based plotting capabilities of System 1®*

Other Measurements / Functions

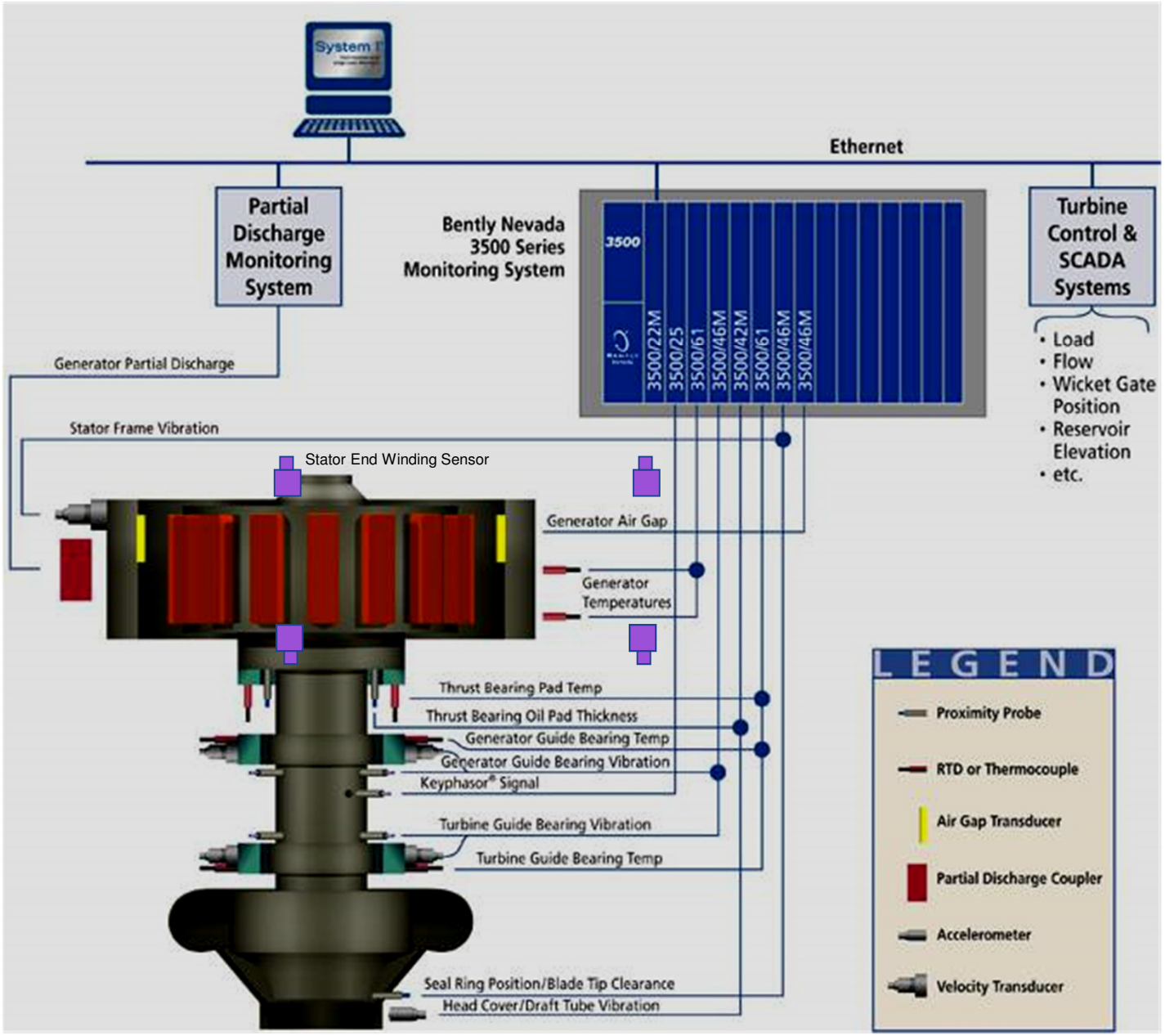
- Temperatures (6 and 16 channel monitors - 3500/60, /61, /65)
- Sole plate position (3500/46 or /42)
- Cavitation (3500/46 or /42)
- Rotor Phase (3500/25)
- Process Variables (3500/62)
- Speed (3500/50)
- Relay Card, 4 0r 16 Channel (3500/32, /33)
- Various Display Options
- Communications Gateway (3500/92 or /91 for Mark VIe)

Hydro Asset Management

System1™

Plant Asset Optimization for Hydro-Power Plants

Typical System Arrangement



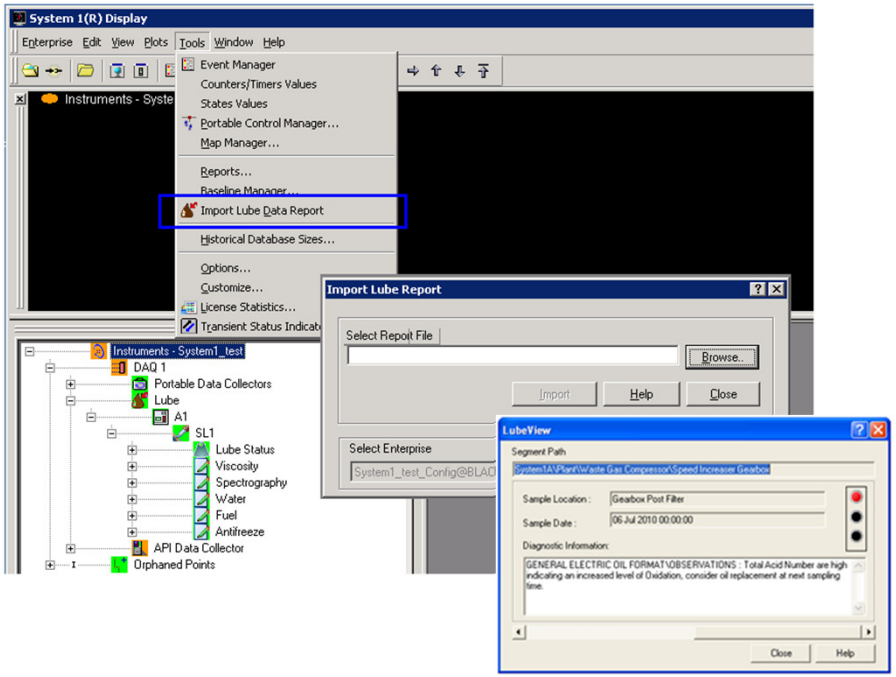
More System 1 Architecture

System 1® Software

- Analysis, trending, correlation, and display
- Hydro Turbine Generator specific plots
- Decision Support^{SM} – Automated data analysis that provides Actionable Information®
- Communication Links to SCADA, Control and Maintenance systems for data correlation
- HydroX RulePaks

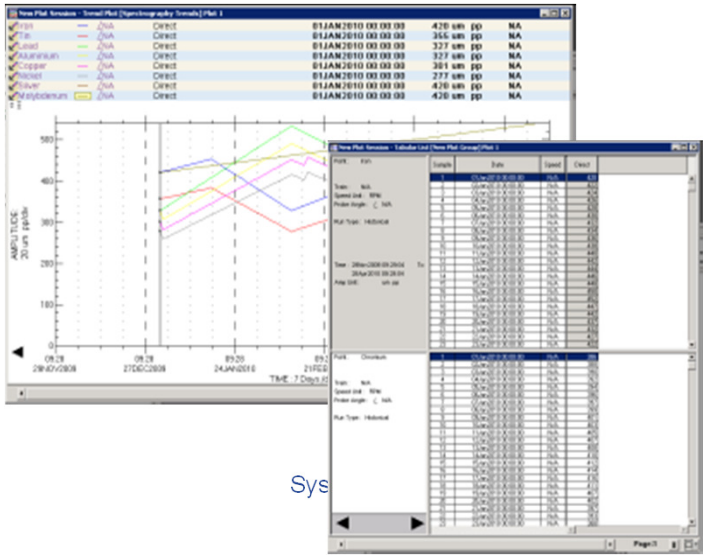
System 1 – Lubricant Data Analysis

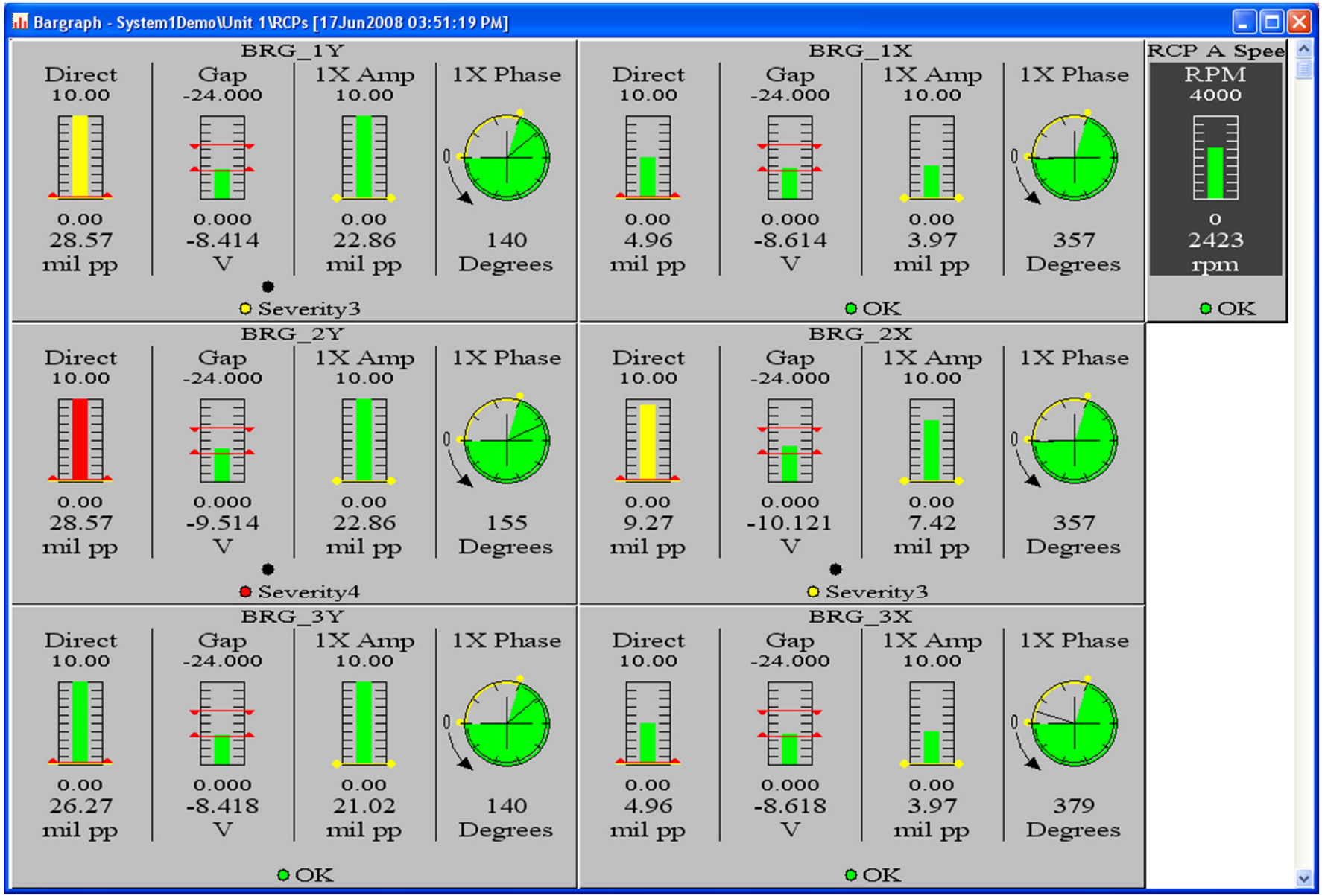
Version 6.7

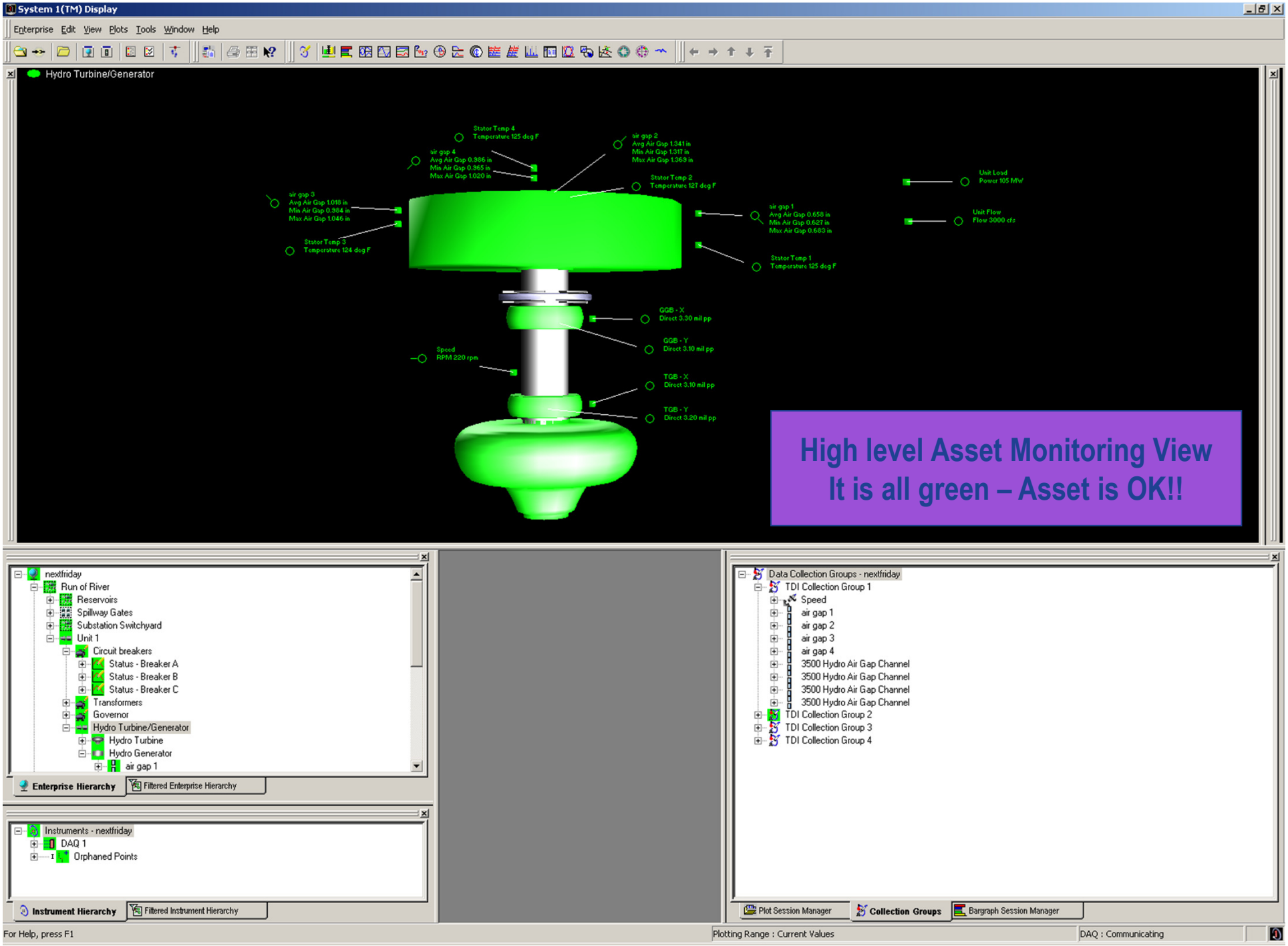


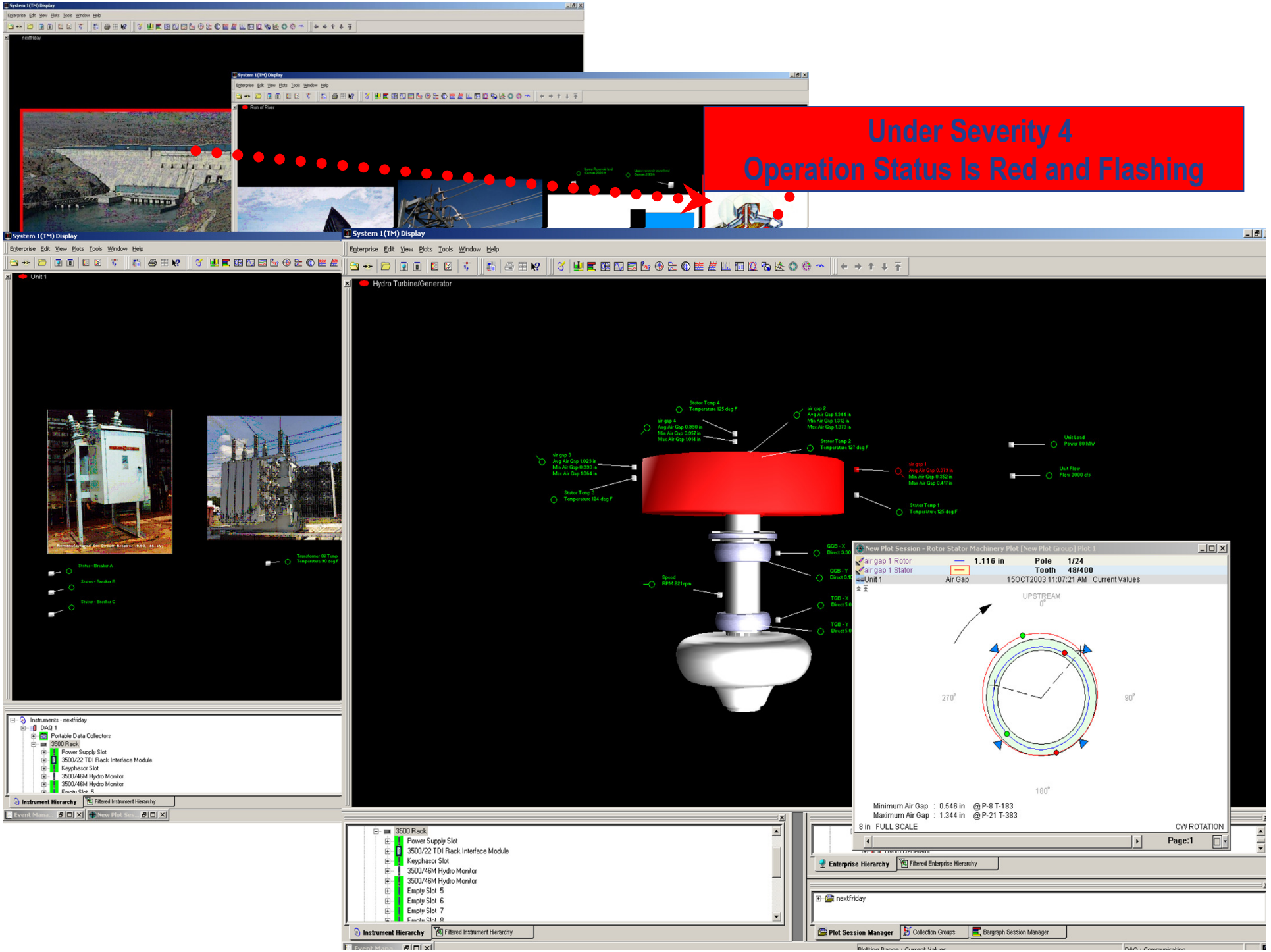
- Import historical data and then import new results over time
- Data is trended
- Data evaluated for alarms and notifications
- Data available for rules and rule packs
- View Lab recommendations / status

- Lubrication data available in all
- Data correlation using plots
- Event/analysis documentation with plot sessions



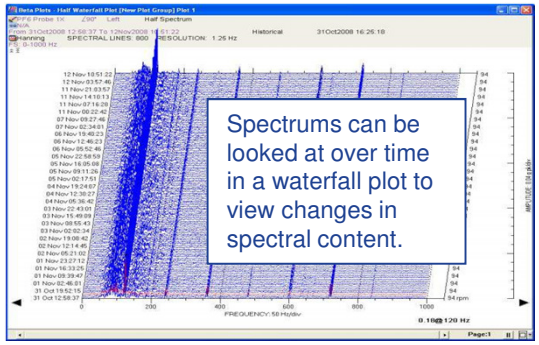

Bargraph - System1Demo\Unit 1\RCPs [17Jun2008 03:51:19 PM]
BRG_1Y
Direct
10.00
0.00
28.57
mil pp
Gap
-24.000
0.000
-8.414
V
1X Amp
10.00
0.00
22.86
mil pp
1X Phase
0
140
Degrees
Severity3
BRG_1X
Direct
10.00
0.00
4.96
mil pp
Gap
-24.000
0.000
-8.614
V
1X Amp
10.00
0.00
3.97
mil pp
1X Phase
0
357
Degrees
OK
RCP A Spee
RPM
4000
0
2423
rpm
OK
BRG_2Y
Direct
10.00
0.00
28.57
mil pp
Gap
-24.000
0.000
-9.514
V
1X Amp
10.00
0.00
22.86
mil pp
1X Phase
0
155
Degrees
Severity4
BRG_2X
Direct
10.00
0.00
9.27
mil pp
Gap
-24.000
0.000
-10.121
V
1X Amp
10.00
0.00
7.42
mil pp
1X Phase
0
357
Degrees
Severity3
BRG_3Y
Direct
10.00
0.00
26.27
mil pp
Gap
-24.000
0.000
-8.418
V
1X Amp
10.00
0.00
21.02
mil pp
1X Phase
0
140
Degrees
OK
BRG_3X
Direct
10.00
0.00
4.96
mil pp
Gap
-24.000
0.000
-8.618
V
1X Amp
10.00
0.00
3.97
mil pp
1X Phase
0
379
Degrees
OK


System 1(TM) Display
Enterprise Edit View Plots Tools Window Help
Hydro Turbine/Generator
Stator Temp 4
Temperature 125 deg F
air gap 4
Avg Air Gap 0.386 in
Min Air Gap 0.365 in
Max Air Gap 1.020 in
air gap 2
Avg Air Gap 1.341 in
Min Air Gap 1.317 in
Max Air Gap 1.369 in
Stator Temp 2
Temperature 127 deg F
air gap 3
Avg Air Gap 1.018 in
Min Air Gap 0.984 in
Max Air Gap 1.046 in
Stator Temp 3
Temperature 124 deg F
air gap 1
Avg Air Gap 0.658 in
Min Air Gap 0.627 in
Max Air Gap 0.683 in
Stator Temp 1
Temperature 125 deg F
Unit Load
Power 105 MW
Unit Flow
Flow 3000 cfs
GGB - X
Direct 3.30 mil pp
GGB - Y
Direct 3.10 mil pp
Speed
RPM 220 rpm
TGB - X
Direct 3.10 mil pp
TGB - Y
Direct 3.20 mil pp
High level Asset Monitoring View
It is all green – Asset is OK!!
nextfriday
Run of River
Reservoirs
Spillway Gates
Substation Switchyard
Unit 1
Circuit breakers
Status - Breaker A
Status - Breaker B
Status - Breaker C
Transformers
Governor
Hydro Turbine/Generator
Hydro Turbine
Hydro Generator
air gap 1
Enterprise Hierarchy
Filtered Enterprise Hierarchy
Instruments - nextfriday
DAQ 1
Orphaned Points
Instrument Hierarchy
Filtered Instrument Hierarchy
Data Collection Groups - nextfriday
TDI Collection Group 1
Speed
air gap 1
air gap 2
air gap 3
air gap 4
3500 Hydro Air Gap Channel
3500 Hydro Air Gap Channel
3500 Hydro Air Gap Channel
3500 Hydro Air Gap Channel
TDI Collection Group 2
TDI Collection Group 3
TDI Collection Group 4
Plot Session Manager
Collection Groups
Bargraph Session Manager
For Help, press F1
Plotting Range : Current Values
DAQ : Communicating

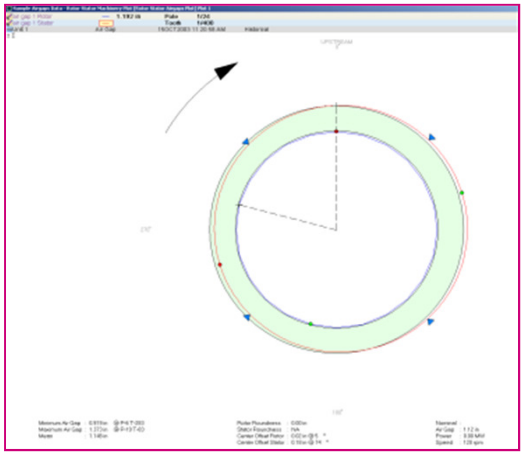

Under Severity 4
Operation Status Is Red and Flashing
System 1(TM) Display
Enterprise Edit View Plots Tools Window Help
Unit 1
Hydro Turbine/Generator
New Plot Session - Rotor Stator Machinery Plot [New Plot Group] Plot 1
air gap 1 Rotor
air gap 1 Stator
1.116 in
Pole 1/24
Tooth 48/400
Unit 1
Air Gap
15OCT2003 11:07:21 AM Current Values
UPSTREAM
0°
90°
180°
270°
Minimum Air Gap : 0.546 in @P-8 T-183
Maximum Air Gap : 1.344 in @P-21 T-383
8 in FULL SCALE
CW ROTATION
Page:1
Instruments - nextfriday
DAQ 1
Portable Data Collectors
3500 Rack
Power Supply Slot
3500/22 TDI Rack Interface Module
Keyphasor Slot
3500/46M Hydro Monitor
3500/46M Hydro Monitor
Empty Slot 5
Empty Slot 6
Empty Slot 7
Instrument Hierarchy
Filtered Instrument Hierarchy
Enterprise Hierarchy
Filtered Enterprise Hierarchy
nextfriday
Plot Session Manager
Collection Groups
Bargraph Session Manager

Hydro-Specific Plot Types in System 1

Spectrum waterfall Plot



Rotor/Stator Profile Plot



Overall Hydro Plant View

Air Gap Plots

(Gap Vs Poles)

Air Gap Plots

(Rotor Shape)

Air Gap Plots

(Combined Rotor And Stator Shape)

X Vs Y

Multiparameter Plots

More Plots / Screen shots

Summary

- Value: tools to implement a maintenance strategy that supports your company's business objectives
- Comprehensive measurements to address mechanical, hydraulic and electrical malfunctions
- Integrated hardware and software platform that adjusts data collection and alarm levels to suit the operating conditions
- Dynamic data plots go beyond alarms and trends to enable quick and accurate troubleshooting and analysis
- Open: export & import data to and from 3rd-party devices
- Scalable: grow capabilities to match changing needs
- Optional HydroX RulePak provides Actionable Information℠
- Full complement of local service and support before, during, and after installation