PROMETHEUS GROUP | USER CONFERENCE

Keys To An Effective Monitoring & Diagnostics Program

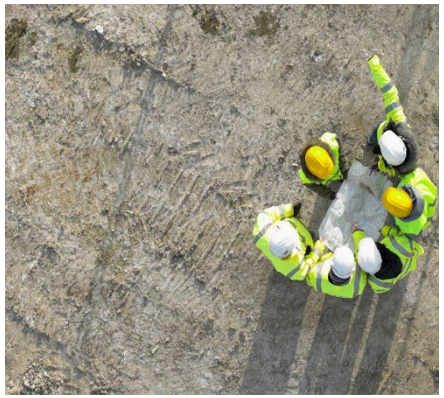
18th April 2023

BLACK & VEATCH

BV – Operating Asset Solutions

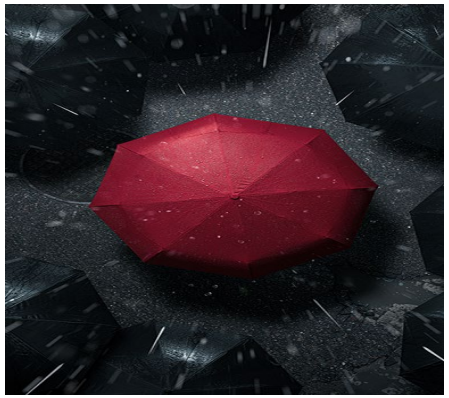
- Operating Analytics

- Modification & Upgrades



- Program Management

- O&M Services



- Staff Augmentation

Operating Analytics

1. ***Monitoring & Diagnostics***

   Stream live data (flows, temperatures, pressures, vibrations, amps, etc.), apply data analytics and monitor/advise from B&V's four global remote monitoring centers.

2. ***Reliability Modeling***

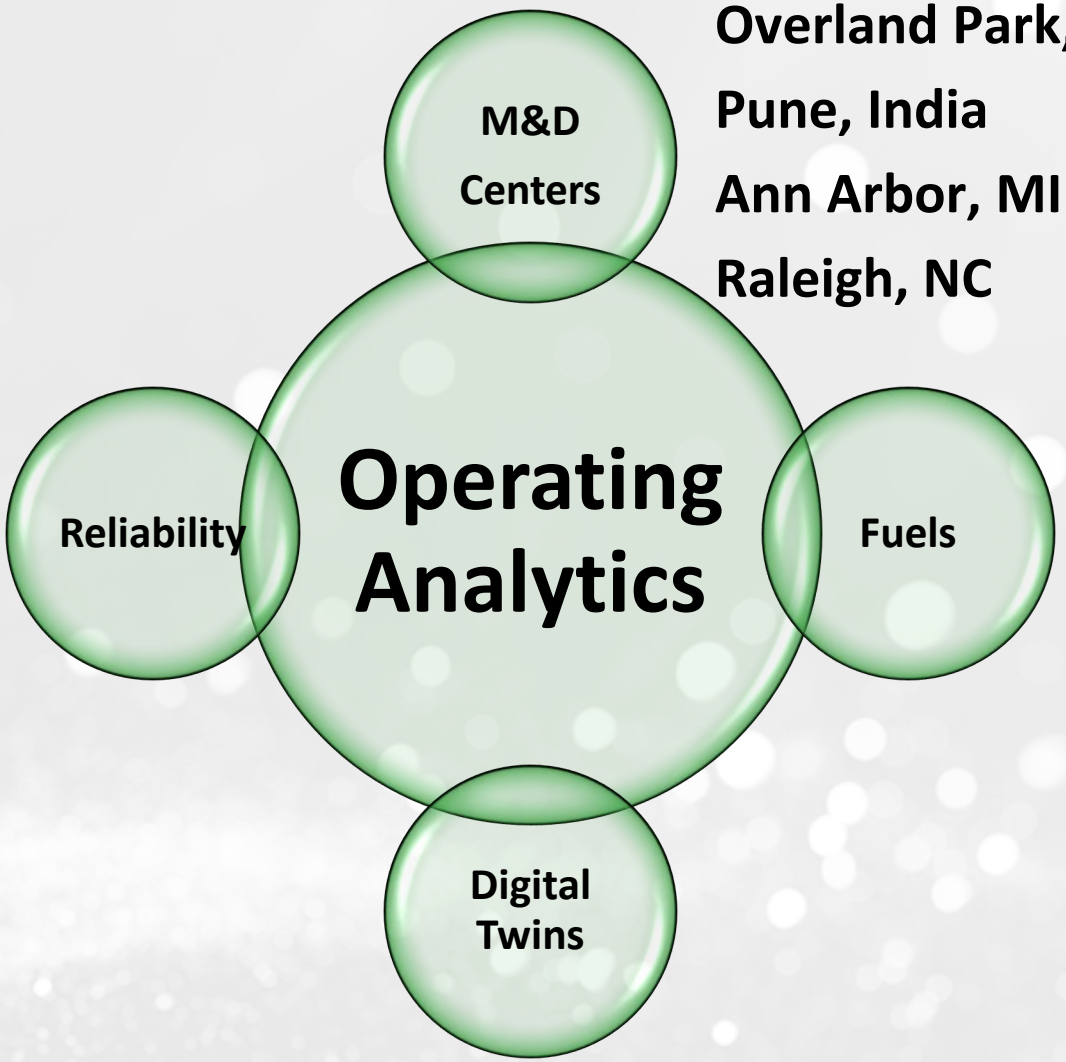
   Ensure asset uptime by quantifying critical risks and identifying strategic opportunities for maintenance and sparing.

3. ***Fuels Modeling***

   Analyze impacts of various fuels on the combustion process including biofuels and hydrogen

4. ***Digital Twins***

   Operational digital twins for improved maintenance planning and asset operation



Overland Park, KS

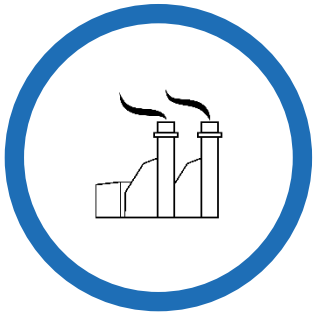
Pune, India

Ann Arbor, MI

Raleigh, NC

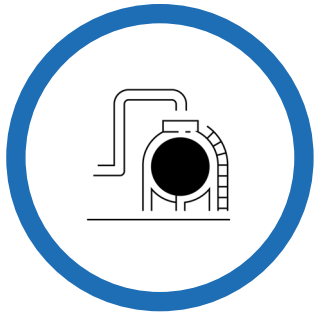
BV's Operating Analytics

Markets Served.



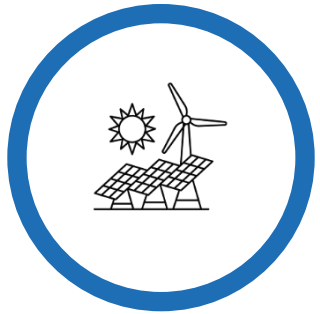
- Boilers & HRSGs
- Combined Cycle CTG
- Simple Cycle CTG
- Transmission

Conventional Power



- LNG/FLNG
- Ammonia + Fertilizer
- Ethanol
- Pipelines
- Refineries

Oil & Gas



- Wind
- BESS
- Utility-scale solar

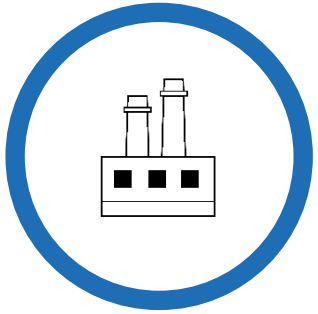
Renewables

monitoring ✓ diagnostics ✓

monitoring ✓ + maintenance ✓

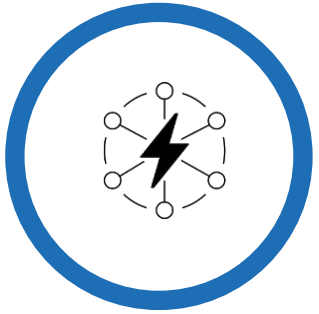
- Wastewater
- Industrial Water
- Water Processing
- Water Distribution

Water



- Pulp & Paper
- Industrial Power
- NextGen Agriculture

Commercial & Industrial



- Telecom
- Hydrogen
- Commercial Solar
- Distributed Generation
- EV Fleet

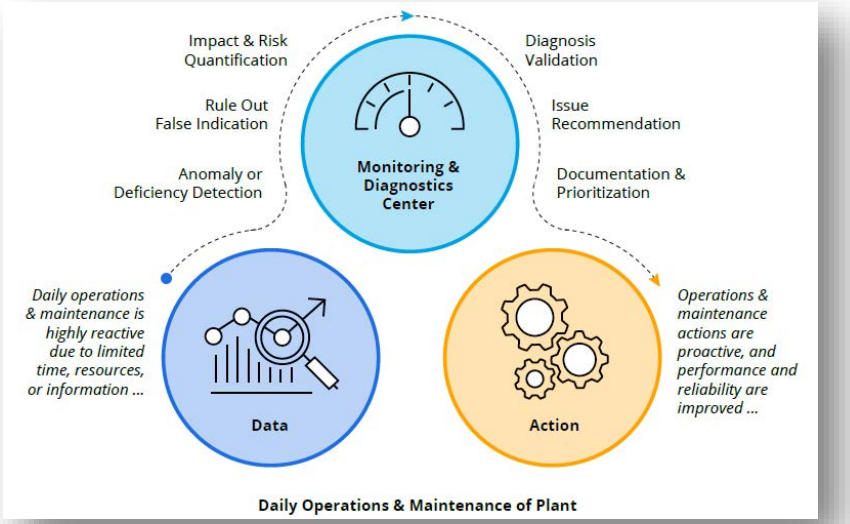
Distributed Infrastructure

Remote Monitoring: Seamless Integration of People, Process and Tools

PEOPLE

- M&D Center with engineers
- Equipment subject matter experts
- Process/system owners
- Software maintenance engineers

PROCESS



- Anomaly detection
- Risk assessment and issue prioritization
- Issue diagnosis and escalation
- Maintenance coordination

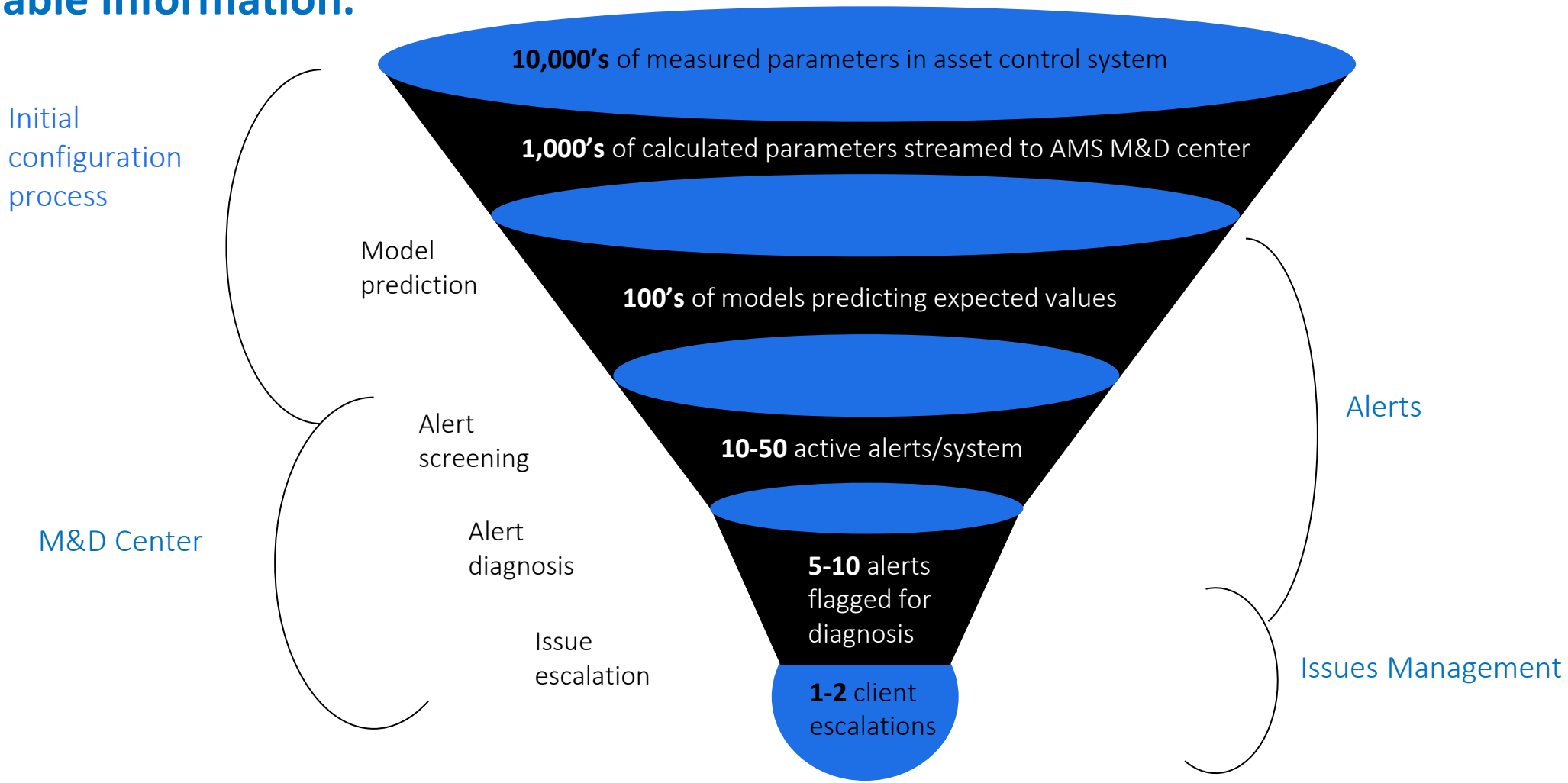
AI/ML ENABLED TOOL

- Real-time process data streaming
- Equipment performance models
- Early fault detection
- Alerting algorithms
- Performance & reliability dashboards

An effective monitoring and maintenance solution is a blend of the right people, processes, and tools…

M&D End State

Actionable Information.



Large data sets dissolved into meaningful, actionable issues

Remote Monitoring Using Pattern Recognition:

"Detect Issues Earlier + Diagnose Fault + Avoid Downtime = Proven ROI"

Learn

Learn from historical data

Model

Build models based on acquired intelligence

Index

Index plant and equipment condition

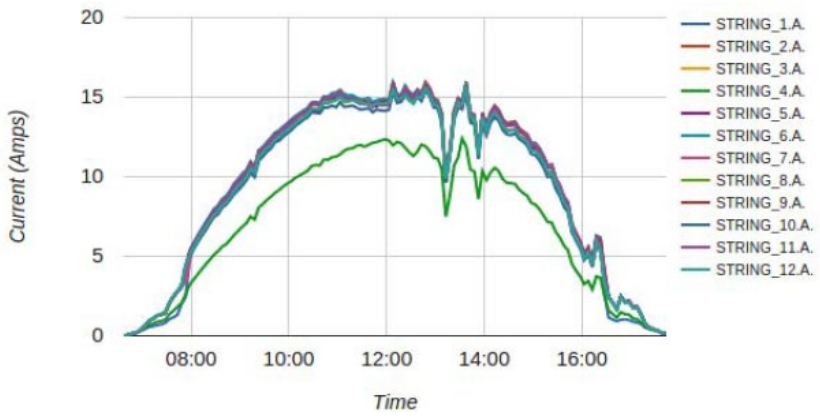
Early Warning

Provide warnings in advance

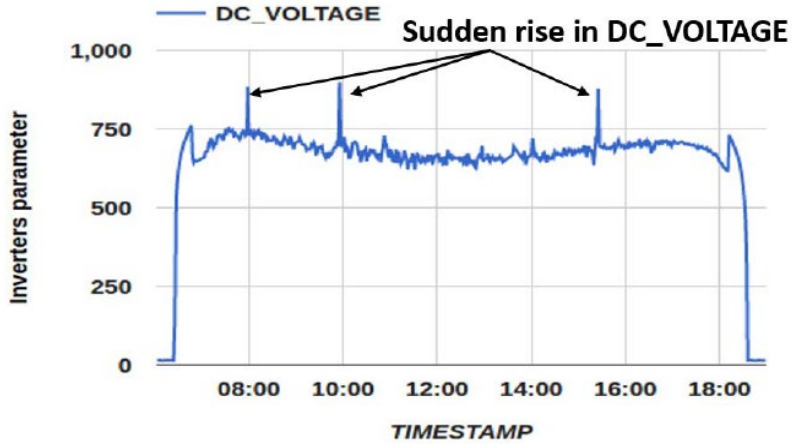
Optimize

Optimize plant with actionable intelligence

Anomaly Detection Technique



Comparison with Respect to a Group



Comparison with Respect to a Past Pattern

M&D Software Applications Should Facilitate the M&D Process

Alert Screening Process

Initial screening to flag items that warrant further investigation

Screening process occurs through out the day

Alert Diagnosing Process

Alerts flagged for further investigation are diagnosed to extent practical

Determination if escalation to lead is warranted.

Escalation to Leads Process

Concerning Alerts with initial diagnosis sent to lead for further assessment and disposition

Determination if escalation to client is warranted

Issue Creation Process

New issue created in Issues Management app or existing issue updated

Includes current observations, trends, impacts, and recommendations (if applicable)

Escalation to Client Process

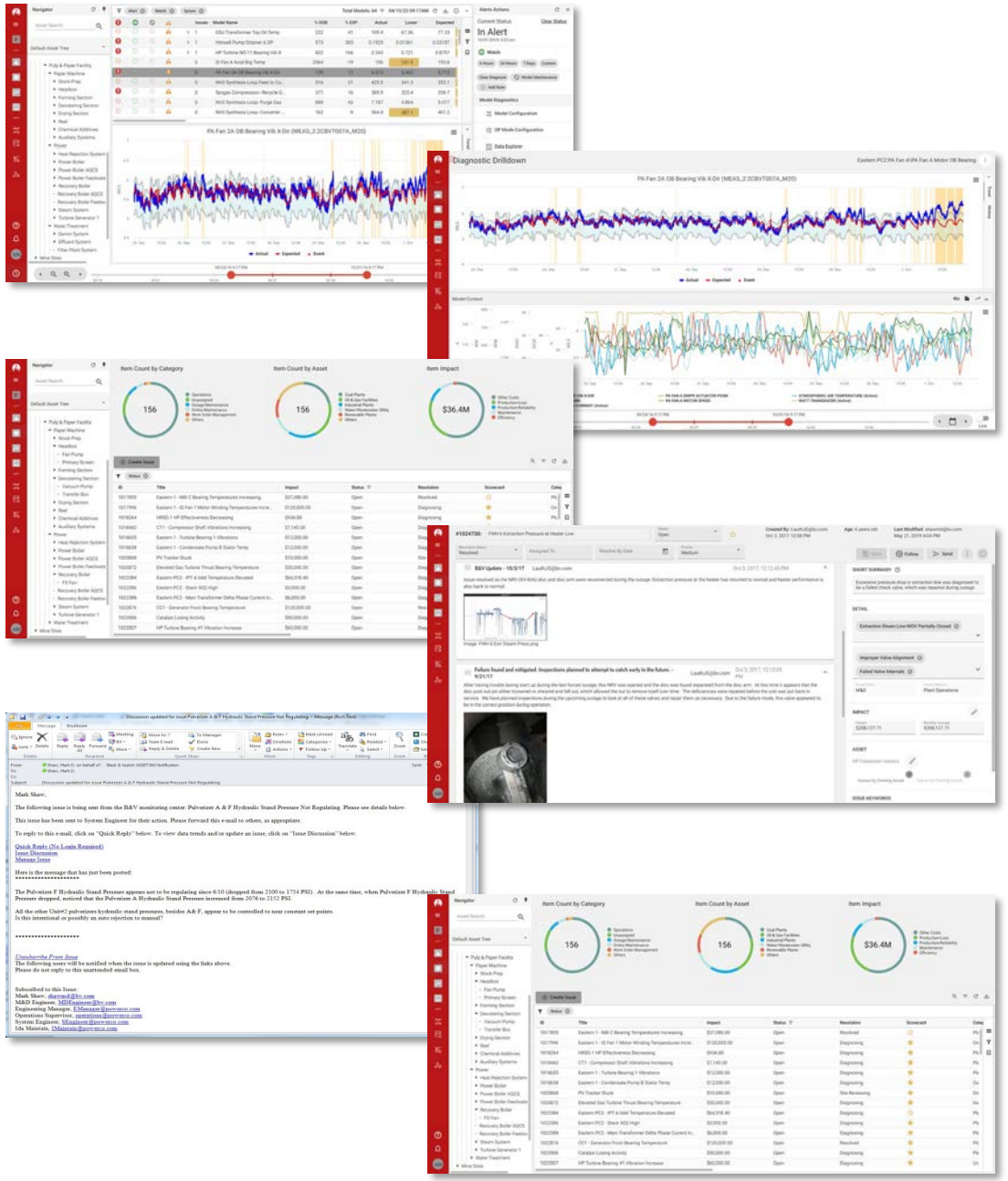
Issue escalated to client via Issues Management app following client approved protocol

Some clients prefer single point of contact, others prefer sending to system owners directly

Issue Life Cycle Process

Issues periodically updated and reviewed with client

Scorecards issued periodically to summarize overall status (monthly, bi-monthly, or quarterly)



Solid Fuels Plant

Gas Fuels

Solar, Batteries & Wind

Wastewater

IC Engines

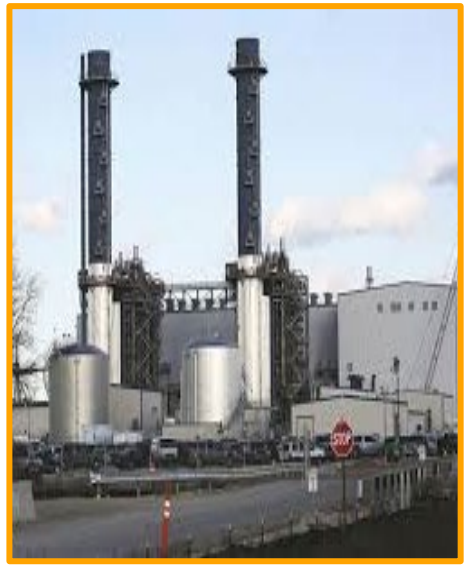
Microgrids

Floating LNG

Paper & Pulp

Chemicals

Ammonia & Urea



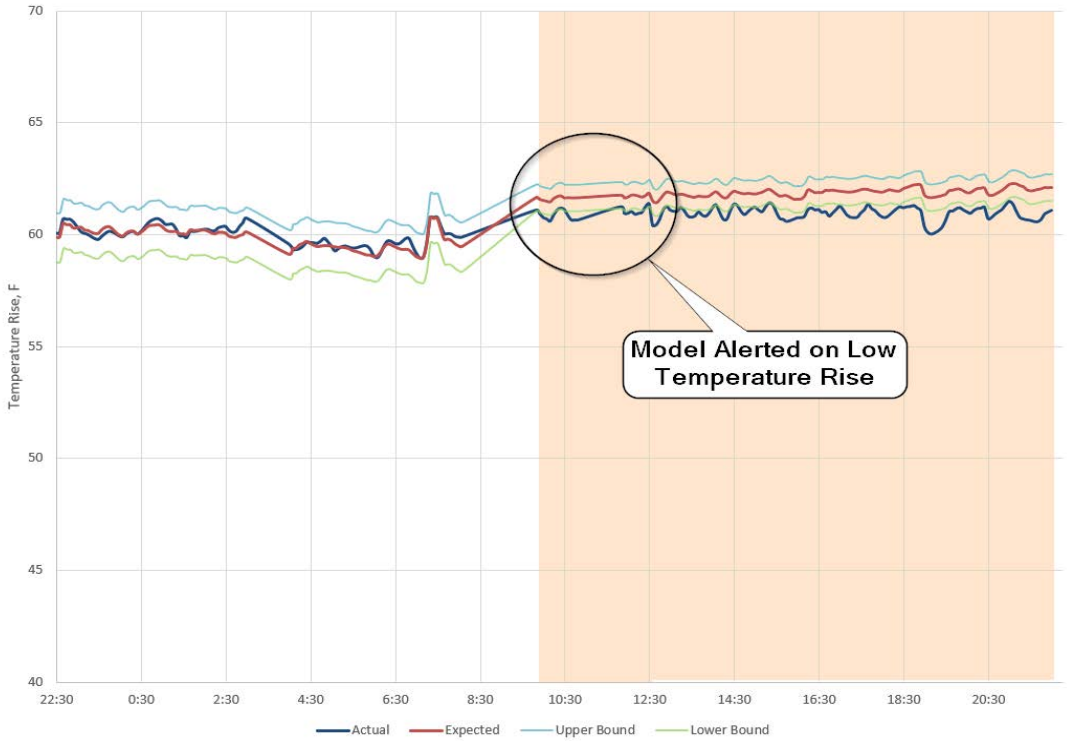
Biofuels

Refinery

Can Be Applied to Nearly Any Technology or Process

Example 1: Extraction Steam Non-Return Valve Failure

- Plant confirmed valve alignment was correct
- Extraction non-return valve was opened and found the disc separated from disc arm
- Potential for highly destructive STG overspeed event on plant trip

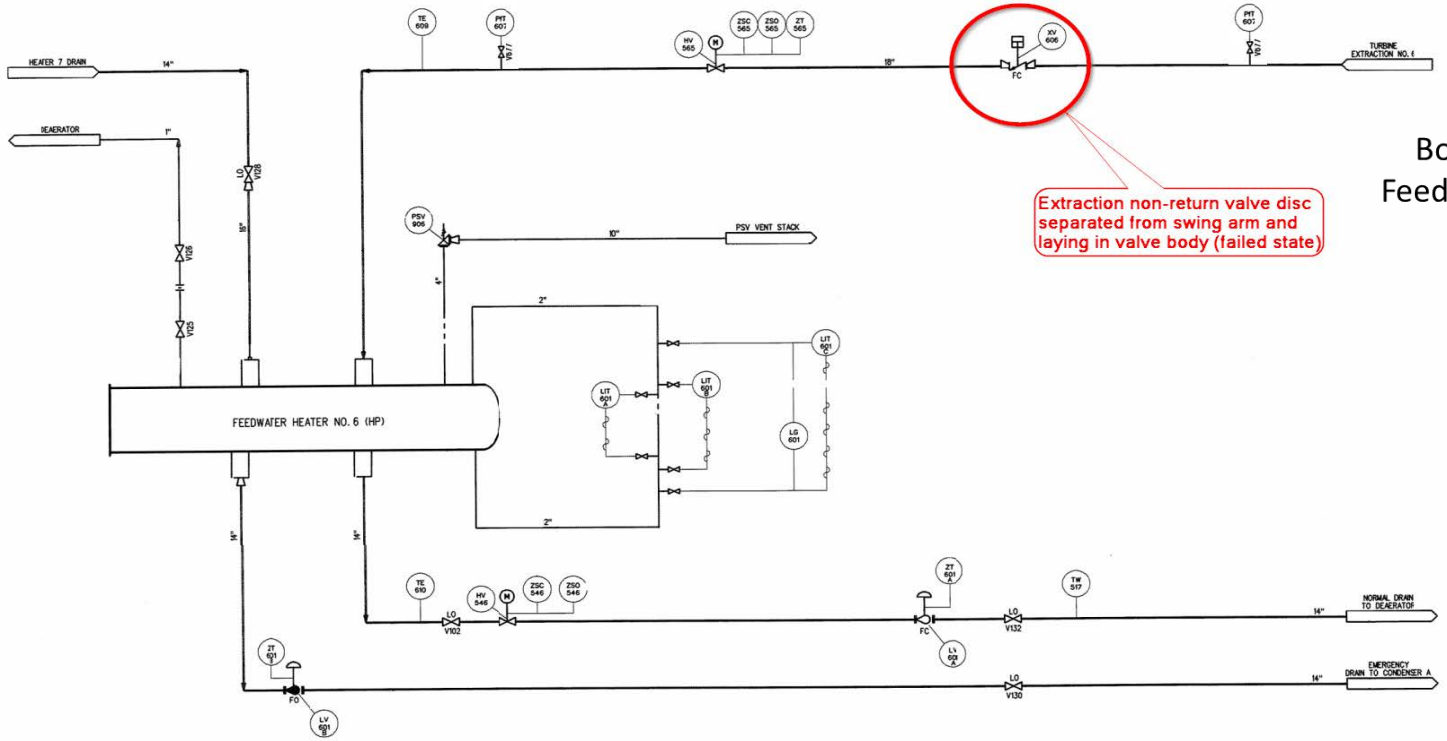


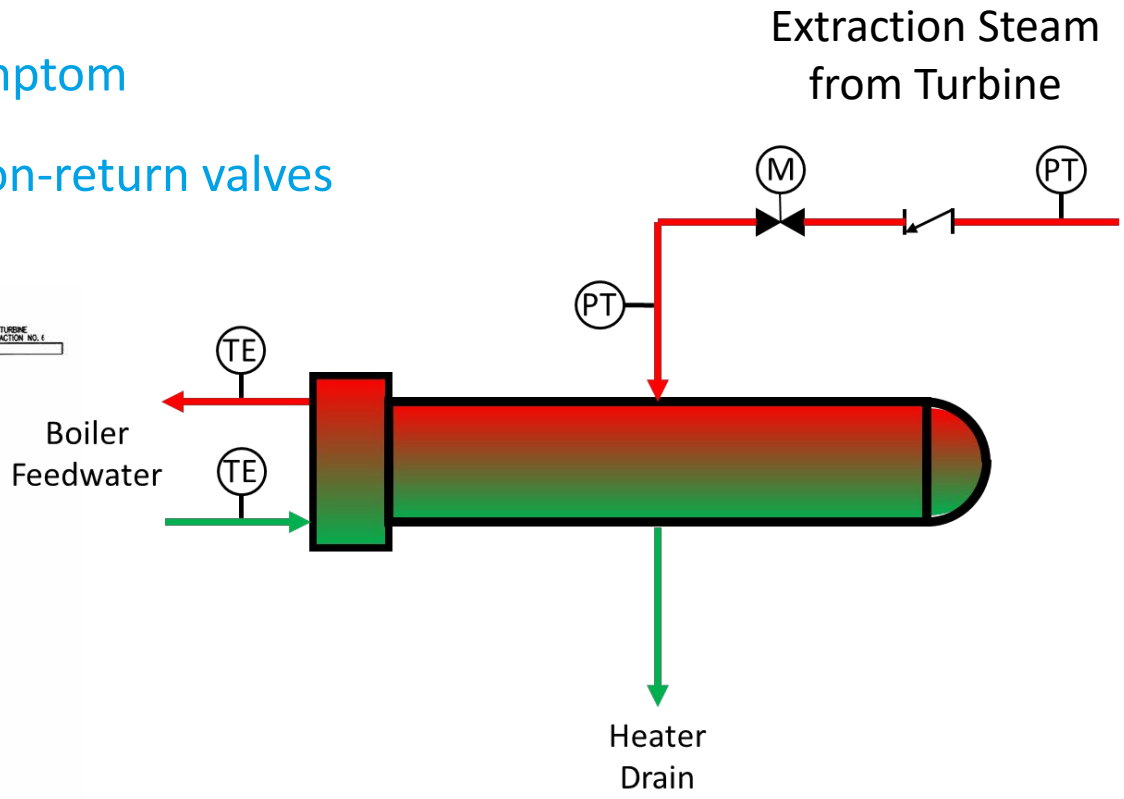
Nut had come off stem and the disc was not attached to the swing arm

Great Find! – But how did we get from this model alert?

Example 1: Extraction Steam Non-Return Valve Failure

- APR model alerted on low feedwater temperature rise
- There are multiple potential failure modes for this symptom
- There is no data around the upstream isolation and non-return valves





M&D engineer had to analyze the problem using P&IDs and deeper dive into plant data

Great Find! – But how did we get here?

Example 1: Extraction Steam Non-Return Valve Failure

#1024730: FWH 6 Extraction Pressure at Heater Low

Status: Open

Created By: LauthJG@bv.com
Oct 3, 2017 12:08 PM

Age: 6 years old

Last Modified: shawmd@bv.com
May 21, 2019 4:04 PM

Resolution Status: Resolved | Assigned To | Resolve By Date | Priority: Medium

Save | Follow | Send

B&V Update - 10/3/17 LauthJG@bv.com Oct 3, 2017, 12:12:45 PM

Issue resolved as the NRV (XV-606) disc and disc arm were reconnected during the outage. Extraction pressure at the heater has returned to normal and heater performance is also back to normal.

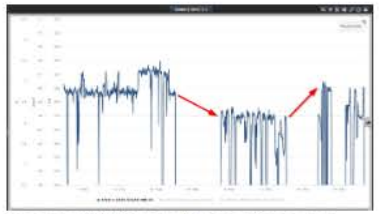


Image: FWH 6 Extr Steam Press.png

Failure found and mitigated. Inspections planned to attempt to catch early in the future. - 9/21/17 LauthJG@bv.com Oct 3, 2017, 12:12:05 PM

After having trouble during start up during the last forced outage, this NRV was opened and the disc was found separated from the disc arm. At this time it appears that the disc post nut pin either loosened or sheared and fell out, which allowed the nut to remove itself over time. The deficiencies were repaired before the unit was put back in service. We have planned inspections during the upcoming outage to look at all of these valves and repair them as necessary. Due to the failure mode, this valve appeared to be in the correct position during operation.

SHORT SUMMARY

Excessive pressure drop in extraction line was diagnosed to be a failed check valve, which was repaired during outage.

DETAIL

Extraction Steam Line MOV Partially Closed

Improper Valve Alignment

Failed Valve Internals

Issue Class: M&D

Issue Category: Plant Operations

IMPACT

Impact: $208,127.71

Monthly Average: $208,127.71

ASSET

HP Feedwater Heaters

Issues by Owning Asset: 1

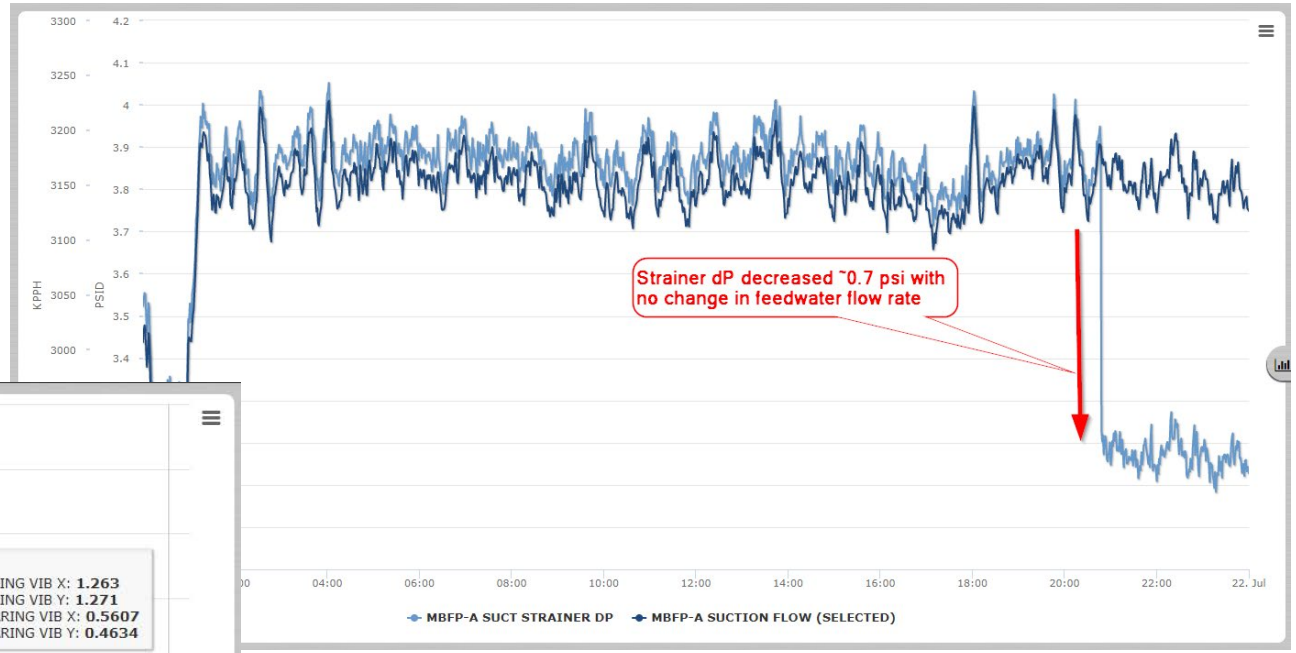
Alerts by Owning Asset: 0

ISSUE KEYWORDS

Value it, Communicate & Help Plant to Resolve

EXAMPLE 2: BFP SUCTION STRAINER FAILURE

- APR model alerted on small decrease (~0.7 psi) in BFP suction strainer dP.
- Validated with 0.7 psi increase in BFP suction pressure at exact same time.
- M&D Center recommended inspection of strainer

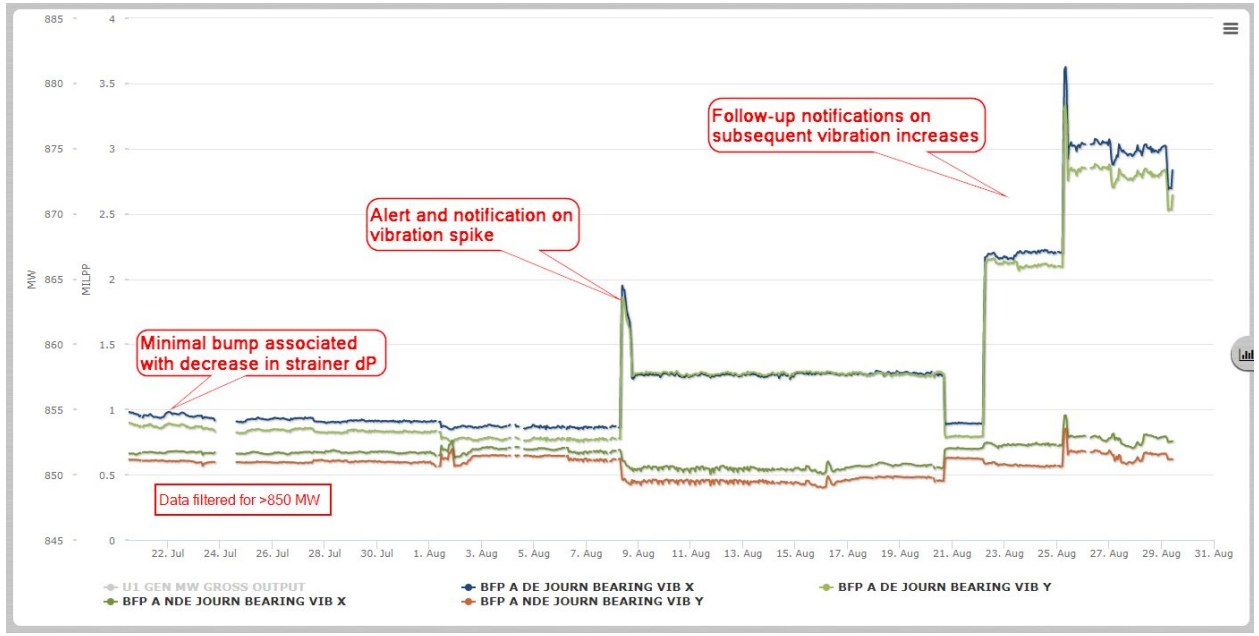


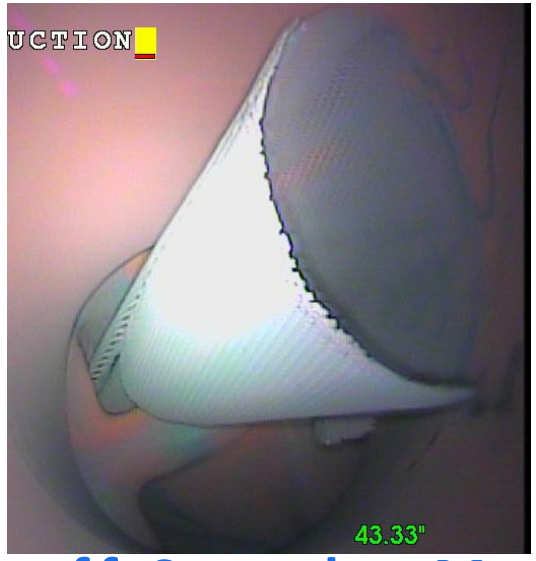
- Minimal vibration increases (<0.05 mils) correlating to time of change in strainer dP.
- Two weeks later, small spike in BFP drive end vibrations, but were still low (1.3 mils).
- Recommended higher resolution vibration measurements be taken locally

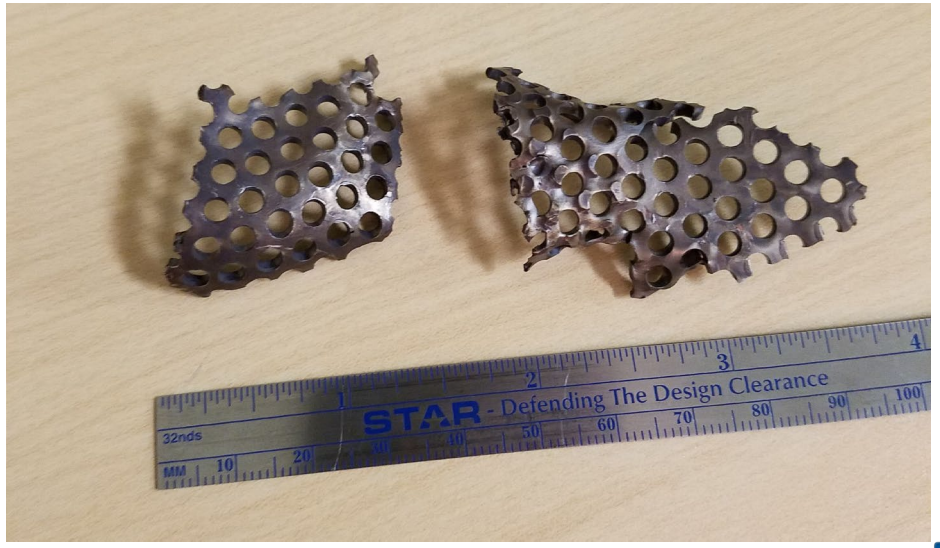
M&D Center Needs to Tell the Story

EXAMPLE 2: BFP SUCTION STRAINER FAILURE

- Plant took vibration measurements locally and monitored closely.
- Plant planned/prepared to replace drive end bearing at next forced outage.
- Borescope inspection of suction line found liberated strainer element pieces lodged in pump suction that were rubbing on shaft.

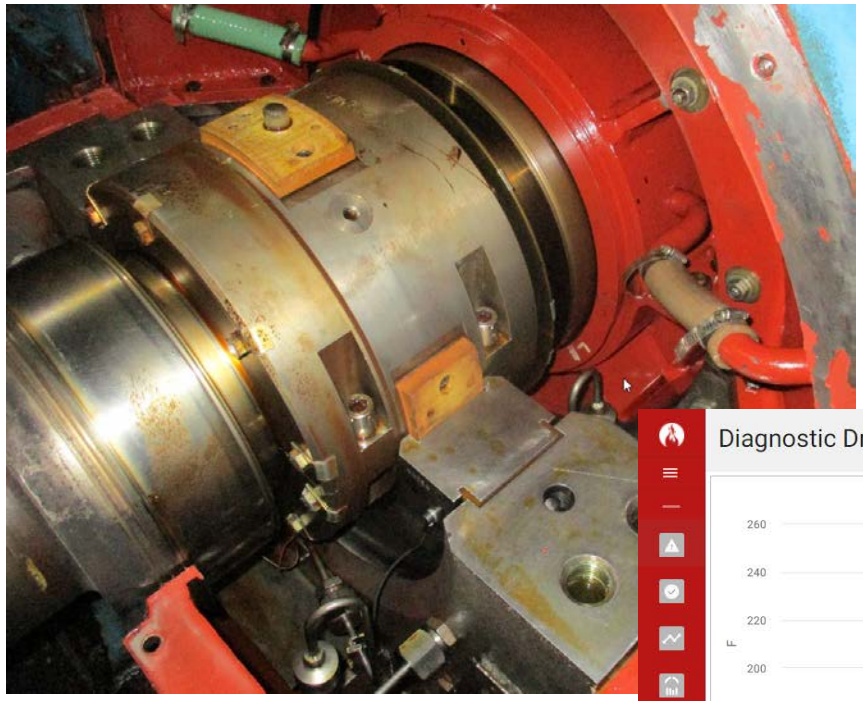




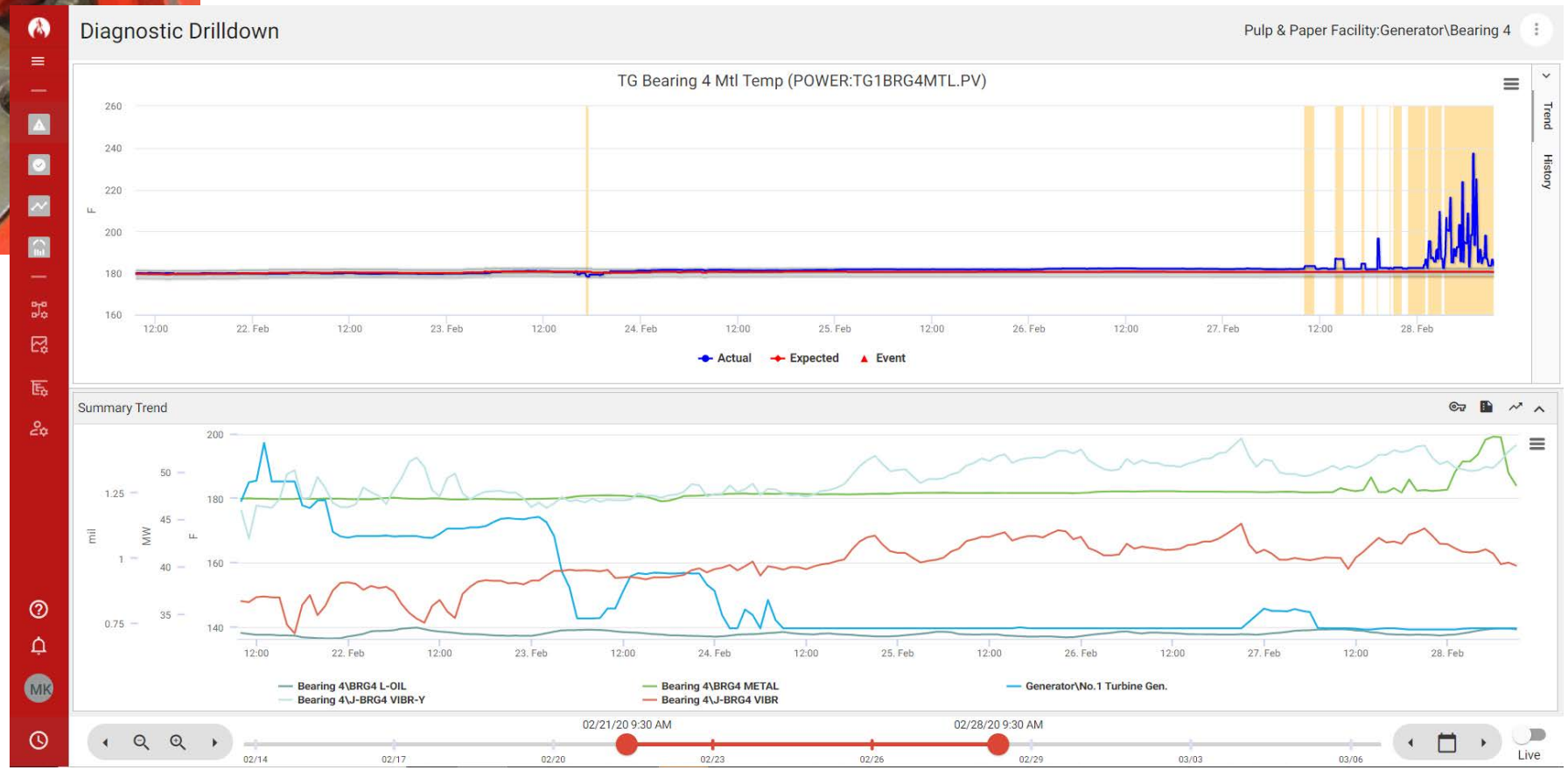


Collaboration with Plant Staff Saved a Major Bearing Replacement

Example 3: Saved Generator Bearing Failure



- Minor Bearing Temp Increase on #4 only.
- Electrical Issue Required Turbine to come down.
- Because of the detected abnormal bearing temp site pulled bearing cap.
- Found hydraulic oil leaking on #4 bearing, causing varnish.



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