Non-Invasive Digitization of Nuclear Power Plants

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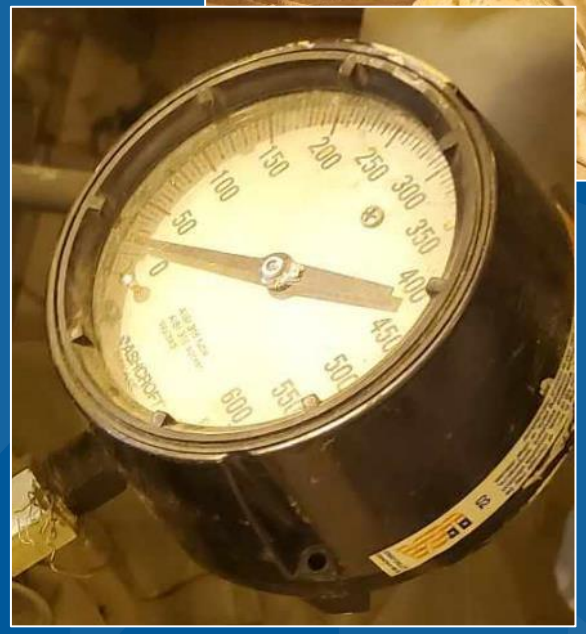
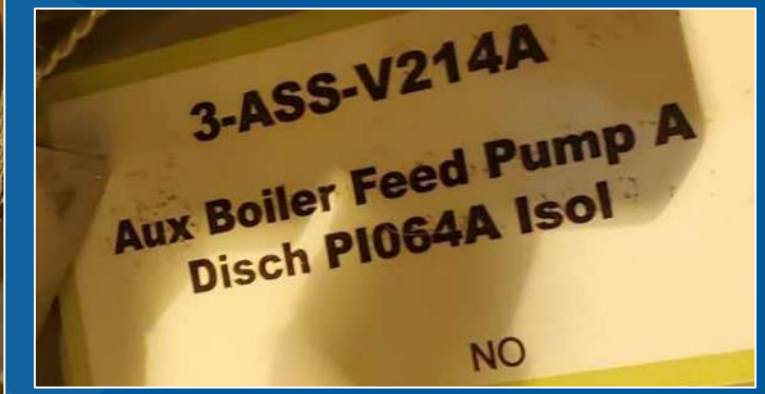
Goals & Objectives

- Goal: How to digitize legacy instrumentation with minimal cost and disruption

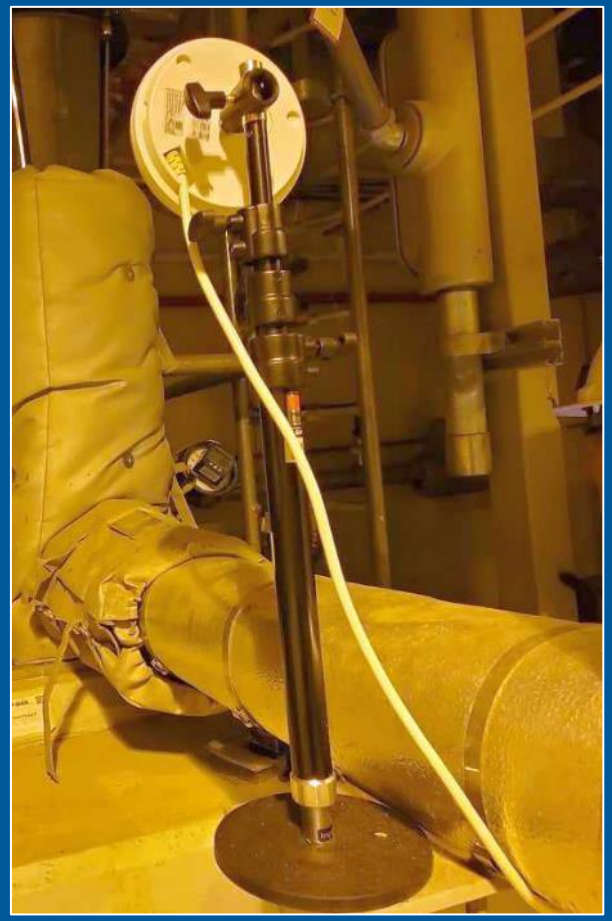
- Objectives:
  - Why digitize existing manual instrumentation
  - How non-invasive technology can help
  - How to deploy – installation, cost, time
  - Integration with existing plant systems
  - Existing nuclear case studies – benefits and ROI
  - Sharing Operational Experience – best practices

Vogtle 3 – Pump Discharge Pressure Monitoring





Manual Pressure Gauges



Axis Camera "Remote Monitoring"

Vogtle 3 – Wireless Gauge Reader Install

LoRaWAN Wireless Gateway and Controller

Wireless Gauge Reader

GBC

CYPRESS ENVIROSYSTEMS™

Readings | Graph | Table | Alarm History | Status | Configuration | Site Settings | Help

Export | Alarm Status

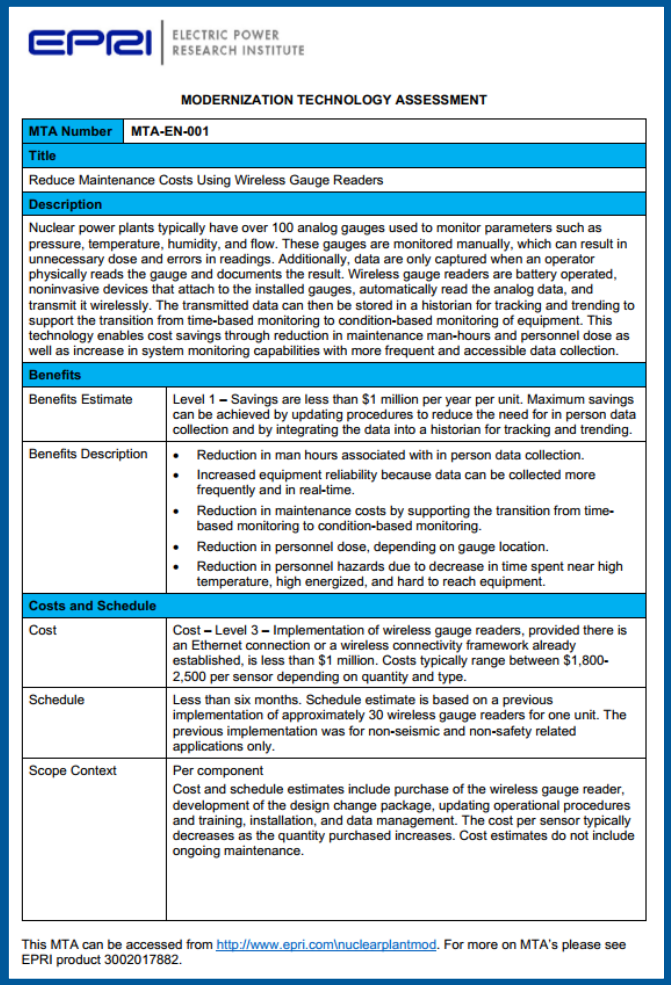
WGR Readings: 2 Items

Timestamp	NodeID	Description	Reading	Units	LCL	UCL	Status
06/27/2023 09:09:06	0/1/1001/0/0/0	3-ASS-MP-04B : Discharge Pressure for 3-ASS-PI064B	12.4	PSI	0	600	OK
06/27/2023 09:12:33	0/1/1002/0/0/0	3-ASS-MP-04A : Discharge Pressure for 3-ASS-PI064A	16.0	PSI	0	600	OK

Web Application and Interface to PI Historian

Technology Deployment – Nuclear Generation

- Duke Energy
- Southern Company
- Xcel Energy
- NextEra
- Constellation
- Bruce Power (Canada)
- Luminant Vistra
- Energy Harbor
- PSEG
- Arizona Public Service
- EPRI Charlotte
- France EDF



EPRI ELECTRIC POWER RESEARCH INSTITUTE

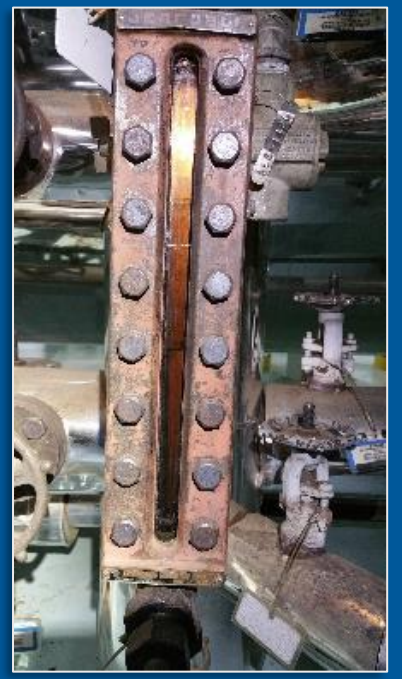
MODERNIZATION TECHNOLOGY ASSESSMENT

MTA Number	**MTA-EN-001**
Title	
Reduce Maintenance Costs Using Wireless Gauge Readers	
Description	
Nuclear power plants typically have over 100 analog gauges used to monitor parameters such as pressure, temperature, humidity, and flow. These gauges are monitored manually, which can result in unnecessary dose and errors in readings. Additionally, data are only captured when an operator physically reads the gauge and documents the result. Wireless gauge readers are battery operated, noninvasive devices that attach to the installed gauges, automatically read the analog data, and transmit it wirelessly. The transmitted data can then be stored in a historian for tracking and trending to support the transition from time-based monitoring to condition-based monitoring of equipment. This technology enables cost savings through reduction in maintenance man-hours and personnel dose as well as increase in system monitoring capabilities with more frequent and accessible data collection.	
Benefits	
Benefits Estimate	Level 1 – Savings are less than $1 million per year per unit. Maximum savings can be achieved by updating procedures to reduce the need for in person data collection and by integrating the data into a historian for tracking and trending.
Benefits Description	• Reduction in man hours associated with in person data collection. • Increased equipment reliability because data can be collected more frequently and in real-time. • Reduction in maintenance costs by supporting the transition from time-based monitoring to condition-based monitoring. • Reduction in personnel dose, depending on gauge location. • Reduction in personnel hazards due to decrease in time spent near high temperature, high energized, and hard to reach equipment.
Costs and Schedule	
Cost	Cost – Level 3 – Implementation of wireless gauge readers, provided there is an Ethernet connection or a wireless connectivity framework already established, is less than $1 million. Costs typically range between $1,800-2,500 per sensor depending on quantity and type.
Schedule	Less than six months. Schedule estimate is based on a previous implementation of approximately 30 wireless gauge readers for one unit. The previous implementation was for non-seismic and non-safety related applications only.
Scope Context	Per component Cost and schedule estimates include purchase of the wireless gauge reader, development of the design change package, updating operational procedures and training, installation, and data management. The cost per sensor typically decreases as the quantity purchased increases. Cost estimates do not include ongoing maintenance.

This MTA can be accessed from http://www.epri.com\nuclearplantmod. For more on MTA's please see EPRI product 3002017882.

EPRI Plant Modernization Toolkit

Recap Problem: Most Plant Data is NOT Digitized



Difficulty of Digitizing Existing Plants

Just to read a simple pressure process value:

- Run wires (power and/or signal)
- I/O panels, termination
- Break seals, leak checks, material compatibility, safety checks
- Engineering assessment, documentation
- Process downtime
- Cybersecurity concerns

Typical traditional solution:
INVASIVE AND COSTLY

Need for Non-Invasive Digitization Solution

Non-Invasive Sensors:

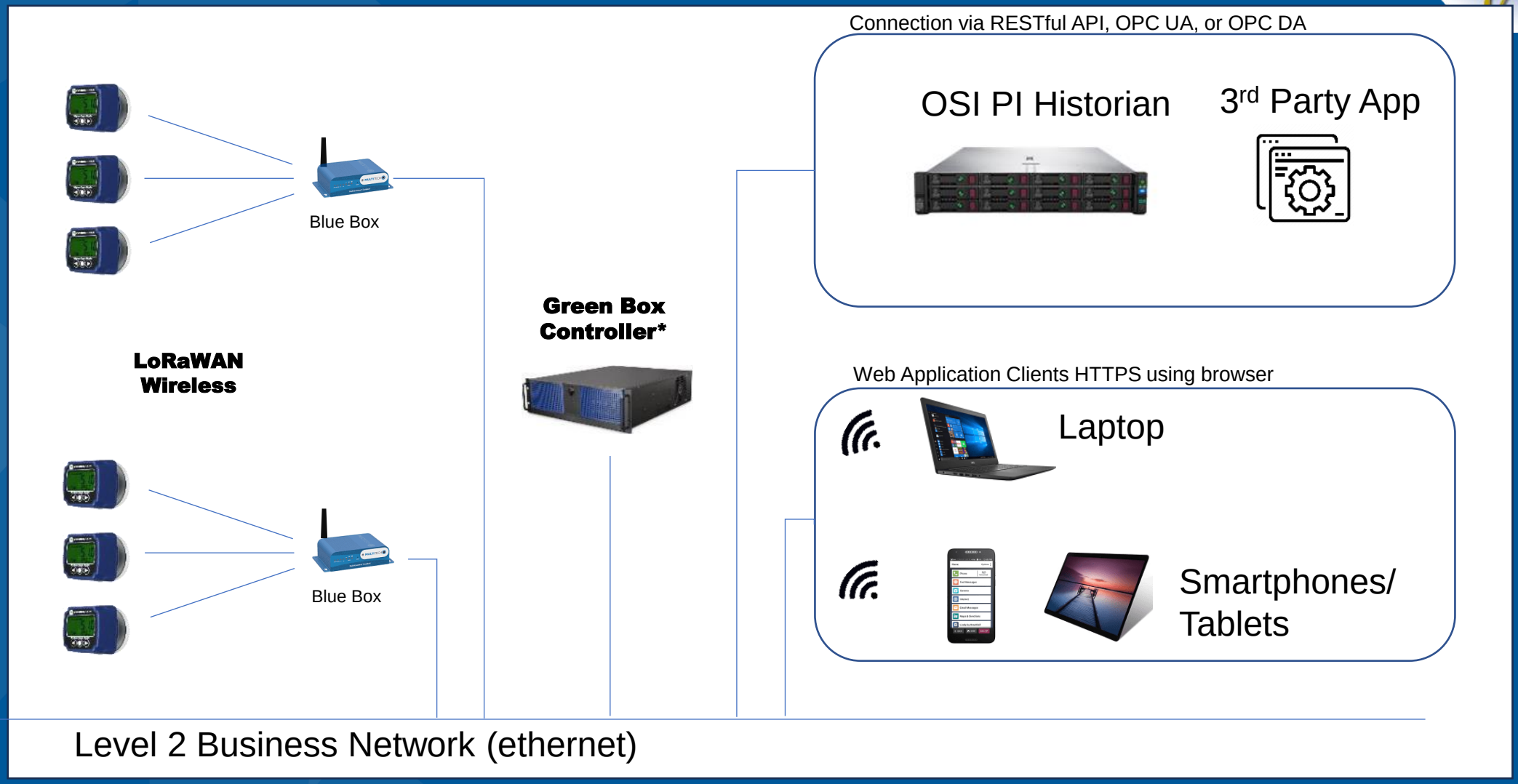
- No breaking seals, no leak checks, no wetted parts
- Lightweight, no structural impact
- No power wires, no signal wires
- Little/no engineering review/analysis
- Takes minutes to install, no plant downtime required
- No new software to install, works with existing plant infrastructure

Solution: Wireless Gauge Reader

- "Electronic Eyeball" reads gauges and transmits readings wirelessly
- Non-invasive, clamp-on to existing gauges in minutes
- No downtime, no leak check, no wiring, no drawings
- Battery life of 3+ years at 15 minute sample rate
- IP56/NEMA 4 rated for outdoor use
- Various size and types of mounting adapters to fit most existing gauges
- Reads dial gauges, hour meters, LED/LCD displays

Typical Installation

LoRaWAN Wireless Backbone



Use of Fleet Spec vs. EC for Deployment

- Following utilities have developed Fleet/Technical Specification to rapidly deploy non-invasive sensors vs. using EC's.

- Allows sensors to be installed within hours of need.
  - Constellation
  - Duke Energy
  - PSEG
  - Vistra-Luminant

Additional Non-Invasive Digitization Solutions

Wireless Indicator Light Reader

- Non-invasive stick-on light sensor
- Small form factor, does not obscure operator view of indicator
- Light weight, optical detection only - minimal engineering review
- Optical detection is “air-gapped” – minimal cyber security review

Wireless Steam Trap/ Pipe Wall Temp Monitor

- Monitor inlet and/or outlet temperatures for steam traps, cycle isolation valves
- Non-invasive clamp-on high temperature sensors – fast installation
- Collect data to detect leaks and other faults – improve thermal performance

Wireless Transducer Reader

- Software configurable I/O and signal conditioning
- Enables wireless remote monitoring of virtually any analog transducer or instrument with the following outputs: 4-20mA, 0-5V, or 0-10V, RS-232, RS-485, thermocouple, thermistor
- 2 channels per device
- Compatible with most existing flow meters, current meters, particle counters, thermocouples, weigh scales, etc.
- Battery life of 3+ years at 15 minute sample rate

Wireless Humidity & Temperature Monitor

- -20 ºC to +70 ºC (-4 ºF to 158 ºF) Temperature Range
- 0 – 100% Relative Humidity Range
- Displays Temperature, Relative Humidity, and Wet Bulb Temperature (optional)
- Used for worker heat stress management, materials life tracking etc.
- Magnetic Mounting for steel walls or columns
- Adhesive Mounting for other surfaces
- Battery life of 3+ years at 15 minute sample rate
- IP56/NEMA 4 rated for outdoor use

Digitizing Camera Images

- Capture images from 3rd party IP Cameras
- Leverage GBC machine vision engine to automatically convert to digital value and store for history, trending, alarming
- No need for human operator to always check camera feed
- Leverages existing network architecture, cyber security approval, OSI PI connectivity

Benefits and ROI

a) Reduce operator labor

b) Equipment Fault Detection/Reduce unplanned downtime
Feed data to Advanced Pattern Recognition models

c) Reduce maintenance cost – transition from scheduled to condition-based maintenance

d) Optimizing plant thermal performance (e.g. feedwater control)

e) Improve worker safety – minimize exposure to hazardous locations

f) Environmental compliance monitoring (e.g. groundwater)

g) Troubleshooting via crash cart, emergent needs

Condition Based Maintenance: Constellation Clinton

- Clinton observed problems with their condensate polisher – suspect that filters are clogging up.
- Short term fix to replace filters more often, but expensive and time intensive.
- Need to monitor filter delta pressure more often to detect when a change is needed – condition based maintenance.
- Only way to do this is sending operators to read pressure gauges. This is a BWR. Dose rates in CP area about 25 mrem/hr.
- WGR used to remotely monitor and trend filter pressures.

Thermal Performance: PSEG Salem

- Monitor condensate vacuum pumps and valves pressures, temperatures, valve position
- Undetected faults can cause >2 MW thermal performance impact
- Trending of data enables early fault detection – data sent to GE Smart Signal
- Improves operator efficiency – reduces need for manual readings.
- Reduces maintenance cost – condition based maintenance

Use of Wireless Gauge Readers to confirm valve transfer function

Read Temperature, Pressure

Read Valve Actuator Position

Alternate WGR mounting to maximize operator visibility of gauge

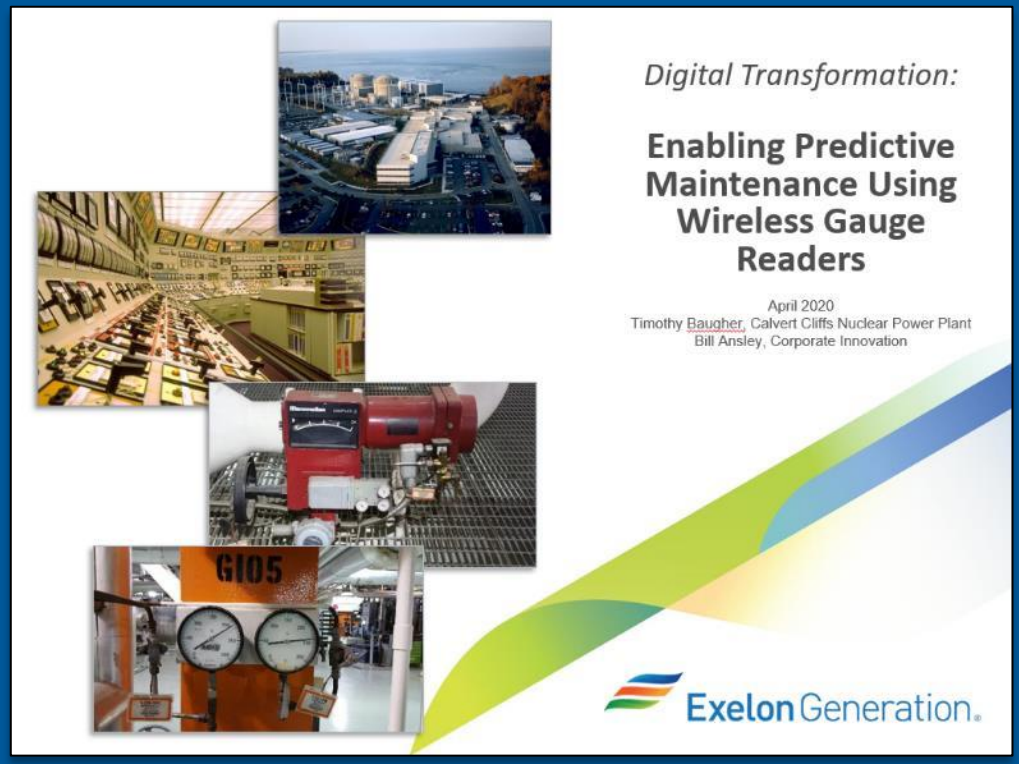
Use of flip doors with gas struts provide hands-free maximum visibility of original gauge

Environmental Monitoring: Duke Brunswick

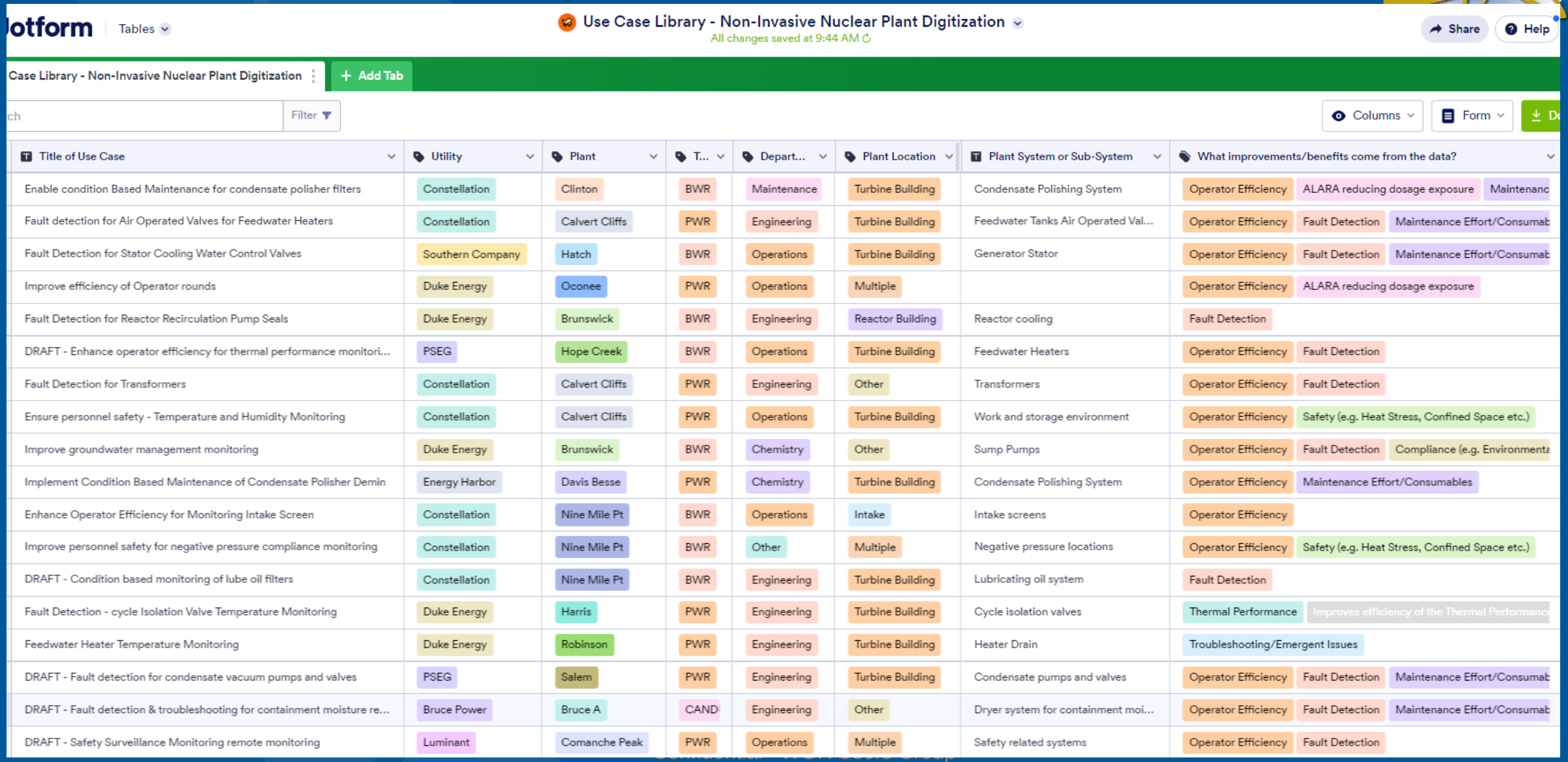
- As part of a Groundwater Protection Plan, Cypress installed wireless gauge readers on sump pump hour meters to track electrical manhole sump pump run-time.
- No current method to monitor sump levels automatically.
- If tritium is detected the sump pump runtime data may be useful to determine where it came from.
- Catch two types of faults:
  - Pumps not running when they should (sump level too high)
  - Pumps running too much (must be a leak)

AOV Fault Detection: Constellation Calvert Cliffs

- Monitor performance and detect failures of Air Operated Valves used to control and maintain feedwater heater tank levels.
- AOV's fail when there is an air leak, drift from calibration, stuck actuator, worn out cam.
- Prior failures caused high-level dump of heater tank and unit shutdown, with costly overtime work to repair.
- Since installing WGR's, Calvert Cliffs detected two emerging failures and repaired them before there was any operational disruption.



Non-Invasive Digitization Use Case Library

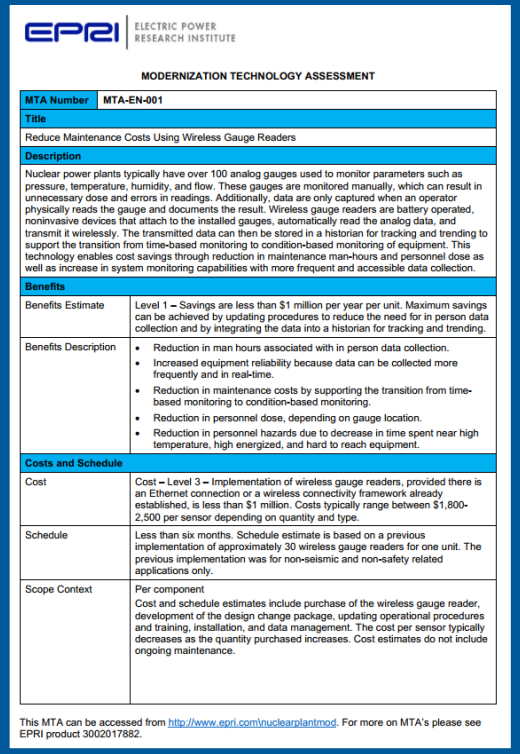


Title of Use Case	Utility	Plant	T...	Depart...	Plant Location	Plant System or Sub-System	What improvements/benefits come from the data?
Enable condition Based Maintenance for condensate polisher filters	Constellation	Clinton	BWR	Maintenance	Turbine Building	Condensate Polishing System	Operator Efficiency; ALARA reducing dosage exposure; Maintenanc
Fault detection for Air Operated Valves for Feedwater Heaters	Constellation	Calvert Cliffs	PWR	Engineering	Turbine Building	Feedwater Tanks Air Operated Val...	Operator Efficiency; Fault Detection; Maintenance Effort/Consumab
Fault Detection for Stator Cooling Water Control Valves	Southern Company	Hatch	BWR	Operations	Turbine Building	Generator Stator	Operator Efficiency; Fault Detection; Maintenance Effort/Consumab
Improve efficiency of Operator rounds	Duke Energy	Oconee	PWR	Operations	Multiple		Operator Efficiency; ALARA reducing dosage exposure
Fault Detection for Reactor Recirculation Pump Seals	Duke Energy	Brunswick	BWR	Engineering	Reactor Building	Reactor cooling	Fault Detection
DRAFT - Enhance operator efficiency for thermal performance monitori...	PSEG	Hope Creek	BWR	Operations	Turbine Building	Feedwater Heaters	Operator Efficiency; Fault Detection
Fault Detection for Transformers	Constellation	Calvert Cliffs	PWR	Engineering	Other	Transformers	Operator Efficiency; Fault Detection
Ensure personnel safety - Temperature and Humidity Monitoring	Constellation	Calvert Cliffs	PWR	Operations	Turbine Building	Work and storage environment	Operator Efficiency; Safety (e.g. Heat Stress, Confined Space etc.)
Improve groundwater management monitoring	Duke Energy	Brunswick	BWR	Chemistry	Other	Sump Pumps	Operator Efficiency; Fault Detection; Compliance (e.g. Environmenta
Implement Condition Based Maintenance of Condensate Polisher Demin	Energy Harbor	Davis Besse	PWR	Chemistry	Turbine Building	Condensate Polishing System	Operator Efficiency; Maintenance Effort/Consumables
Enhance Operator Efficiency for Monitoring Intake Screen	Constellation	Nine Mile Pt	BWR	Operations	Intake	Intake screens	Operator Efficiency
Improve personnel safety for negative pressure compliance monitoring	Constellation	Nine Mile Pt	BWR	Other	Multiple	Negative pressure locations	Operator Efficiency; Safety (e.g. Heat Stress, Confined Space etc.)
DRAFT - Condition based monitoring of lube oil filters	Constellation	Nine Mile Pt	BWR	Engineering	Turbine Building	Lubricating oil system	Fault Detection
Fault Detection - cycle Isolation Valve Temperature Monitoring	Duke Energy	Harris	PWR	Engineering	Turbine Building	Cycle isolation valves	Thermal Performance; Improves efficiency of the Thermal Performanc
Feedwater Heater Temperature Monitoring	Duke Energy	Robinson	PWR	Engineering	Turbine Building	Heater Drain	Troubleshooting/Emergent Issues
DRAFT - Fault detection for condensate vacuum pumps and valves	PSEG	Salem	PWR	Engineering	Turbine Building	Condensate pumps and valves	Operator Efficiency; Fault Detection; Maintenance Effort/Consumab
DRAFT - Fault detection & troubleshooting for containment moisture re...	Bruce Power	Bruce A	CAND	Engineering	Other	Dryer system for containment moi...	Operator Efficiency; Fault Detection; Maintenance Effort/Consumab
DRAFT - Safety Surveillance Monitoring remote monitoring	Luminant	Comanche Peak	PWR	Operations	Multiple	Safety related systems	Operator Efficiency; Fault Detection

Current Deployments

- Duke Energy (Fleetwide: Oconee, Robinson, Brunswick, Harris, Catawba, McGuire)
- Constellation Energy (Calvert, Braidwood, Clinton, JAF, Nine Mile Point, Limerick, Ginna, Peach Bottom)
- Southern (Fleetwide: Farley, Hatch, Vogtle)
- Xcel Energy (Fleetwide: Prairie Island, Monticello)
- NextEra (Fleetwide: Turkey Point, St. Lucie, Point Beach, Seabrook)
- Vistra Luminant (Comanche Peak, Davis Besse)
- STP Nuclear (South Texas)
- Nebraska Public Power District (Cooper)
- PSEG (Fleetwide: Salem, Hope Creek)*
- Bruce Power (Canada)
- Arizona Public Service (Palo Verde*)
- Entergy Vermont Yankee (1 unit – decommissioned)
- EPRI Charlotte - Nuclear Applications Center (installed)
- France EDF (pilot deployment)

* Pending Installation



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EPRI Plant Modernization Toolkit

Summary

- Non-Invasive technologies can digitize legacy instrumentation with minimal cost and disruption
- Proven Return On Investment for Operator Efficiency, Fault Detection (avoided down-time), Thermal Performance, ALARA, reduced maintenance etc.
- Extensive Operational Experience library of Use Cases, Specifications, and Best Practices available from existing users.

Q&A

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