Digitization of Nuclear Plants

Wireless Gauge Reader Applications and ROI

2/28/2023

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WGR Deployments – Nuclear Generation

- Duke Energy (Fleetwide all six plants, 11 units)
- Constellation Energy (Calvert Cliffs, Nine Mile Point, Braidwood, Clinton, Limerick, JAF, Ginna)
- Xcel Energy (Fleetwide: Prairie Island, Monticello)
- NextEra (Fleetwide: Turkey Point, St. Lucie, Point Beach, Seabrook)
- Bruce Power (Canada)
- Arizona Public Service (Palo Verde*)
- Luminant (Comanche Peak)
- Southern (Farley, Hatch*)
- Entergy Vermont Yankee (1 unit – decommissioned)
- EPRI Charlotte - Nuclear Applications Center (installed)
- France EDF (pilot deployment)

* Pending Installation

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

There are thousands of these devices with critical process data, but it costs over $20,000 to instrument each one using conventional technology, plus cost of process downtime.

Typical traditional solution:
INVASIVE AND COSTLY

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Need for Non-Invasive Digitization Technology

Non-Invasive Sensors:

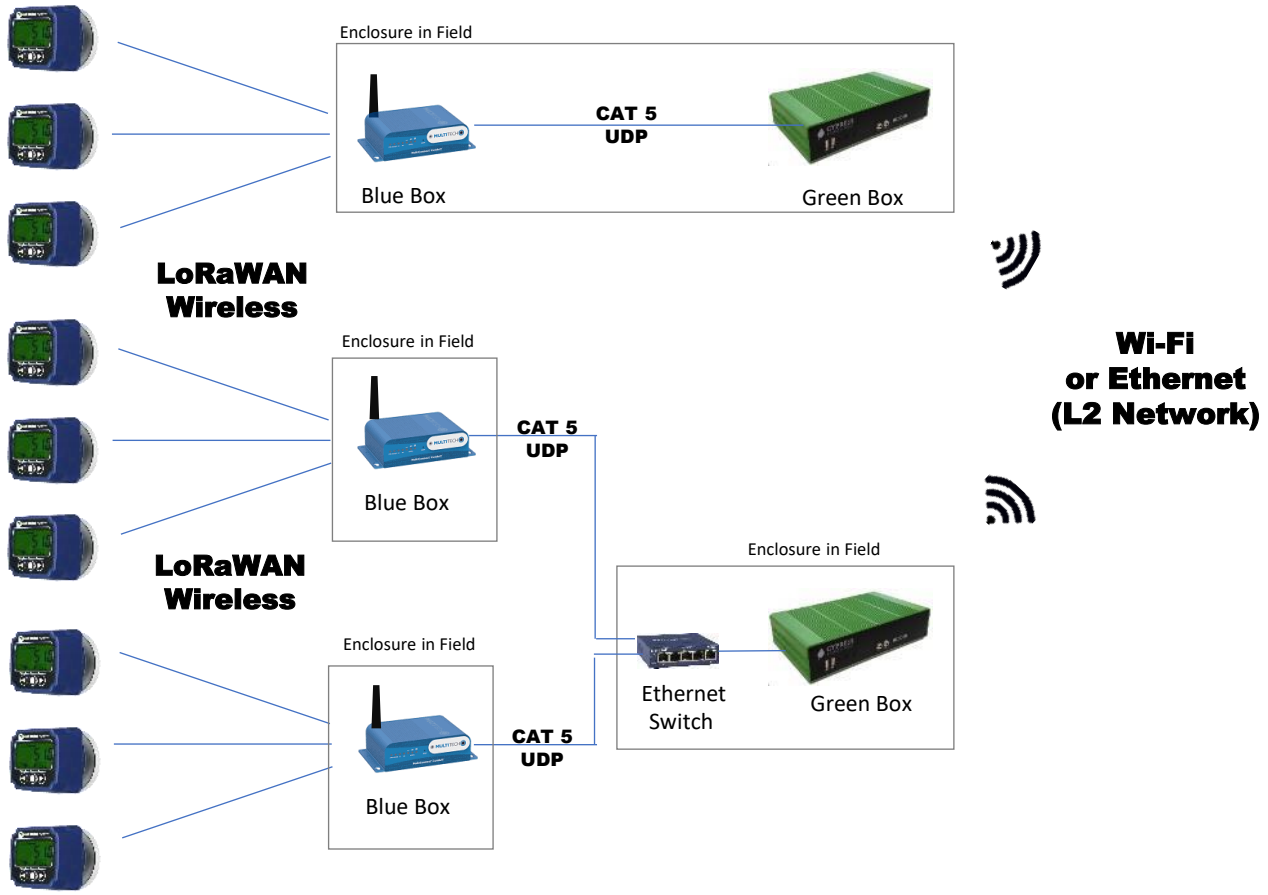
- No breaking seals, no leak checks, no wetted parts
- Lightweight, no structural impact
- No power wires, no signal wires
- Little/no engineering review/analysis
- Takes minutes to install, no plant downtime required
- No new software to install, works with existing plant infrastructure

Cypress 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

Typical Deployment Architecture



Wi-Fi
or Ethernet
(L2 Network)

Connection via RESTful API, OPC UA, or OPC DA

OSI PI / R*Time Historian

3rd Party App

Web Application Clients HTTPS using browser

Laptop

Smartphones/
Tablets

Wireless Gauge Reader

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Options for OSI PI / R*Time Historian Connection

Option 1: RESTful API

https://livelibrary.osisoft.com/LiveLibrary/content/en/web-api-v8/GUID-9330057F-C995-4721-A10F-29F3C1EB3E8E

← Used for R*Time

Option 2: OPC UA

https://techsupport.osisoft.com/Products/PI-Interfaces-and-PI-Connectors/PI-Connector-for-OPC-UA/Interface-Details/

Option 3: OPC DA – with OSI PI Connector

http://cdn.osisoft.com/interfaces/1753/PI_OPCInt_2.3.11.0.doc

YouTube instructional video:

https://www.youtube.com/playlist?list=PLMcG1Hs2JbctX6QcnqgBxTUy1hEniSd0l

← Most commonly used today for PI

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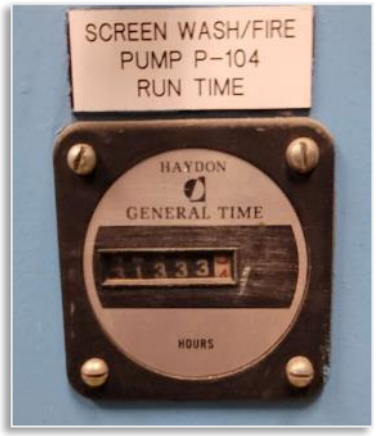
Cypress Family of Non-Invasive Digitization Solutions

Wireless Digit Reader

- Reads numeric indicators
- Exactly same form factor as Wireless Gauge Reader
- Should not require additional engineering review/approval
- Has different firmware than WGR
- Wireless transmission duty cycle is higher - battery life about 30% of WGR. Use slower sample rate to compensate



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
- Optional enclosures for NEMA 6, IP 67 protection
- Enables data logging to enable trend analysis, notification, or statistical process control

Wireless Humidity and 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

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
- Will require EMI exclusion distance consideration depending on type of equipment

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Wireless Steam Trap/Pipe Wall Temp Monitor

Leaking Traps Waste Energy

Typical Steam Trap

- Traps are a necessary part of the steam distribution system, usually hundreds of units per site
- 15-20% average failure rate; leaks steam
- Failed traps lose $5,000 per year (1/8” orifice)
- Manual inspection typically done annually – labor intensive, do not catch problems in timely manner
- Solution: Wireless steam trap monitor detects faults and alarms on error, avoiding expensive leak loss
- Non-invasive installation: no breaking seals, wireless, integrates with BMS
- Battery life of 3+ years at typical sample rates
- IP65/NEMA 4 rated for outdoor use
- One year payback on investment

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Return on Investment
Use Cases

Benefit Categories

- Improve operator efficiency
- Equipment fault detection/reduce unplanned downtime, feed data to OSI PI and Advanced Pattern Recognition models (e.g. Predix, SmartSignal, Prism)
- Reduce maintenance cost – transition from scheduled preventive to condition-based maintenance
- Optimizing plant thermal performance
- Improve worker safety – minimize exposure to hazardous locations, ALARA
- Environmental compliance monitoring
- Troubleshooting via crash cart, emergent needs

Selected Operational Experience - Discussion

- Duke Energy Oconee: improved efficiency of operator rounds after implementation of WGRs.
- Constellation Calvert Cliffs: Early fault detection in feedwater heater tank level controls - avoided unplanned downtime
- Constellation Clinton: Implement condition-based maintenance for condensate polishing filter changeout
- Duke Brunswick (BWR): ALARA, to reduce dose rates for workers where possible for routine tasks
- Duke Harris: improve thermal performance by detecting and eliminating leaks in steam isolation valves
- NextEra Turkey Point: Monitor bearing temperatures and head pressure for condensate pumps, recirc pumps, component cooling pumps etc. to detect early failure signs
- Duke Brunswick: Monitor run-time for certain sump pumps as part of groundwater protection plan
- Limerick Comanche Peak: monitor ambient temperature, humidity and wet bulb for worker heat safety and material life impact
- Constellation Three Mile Island: crash cart for troubleshooting emergent issues (prior to decommissioning)

Operator Remote Monitoring - Duke

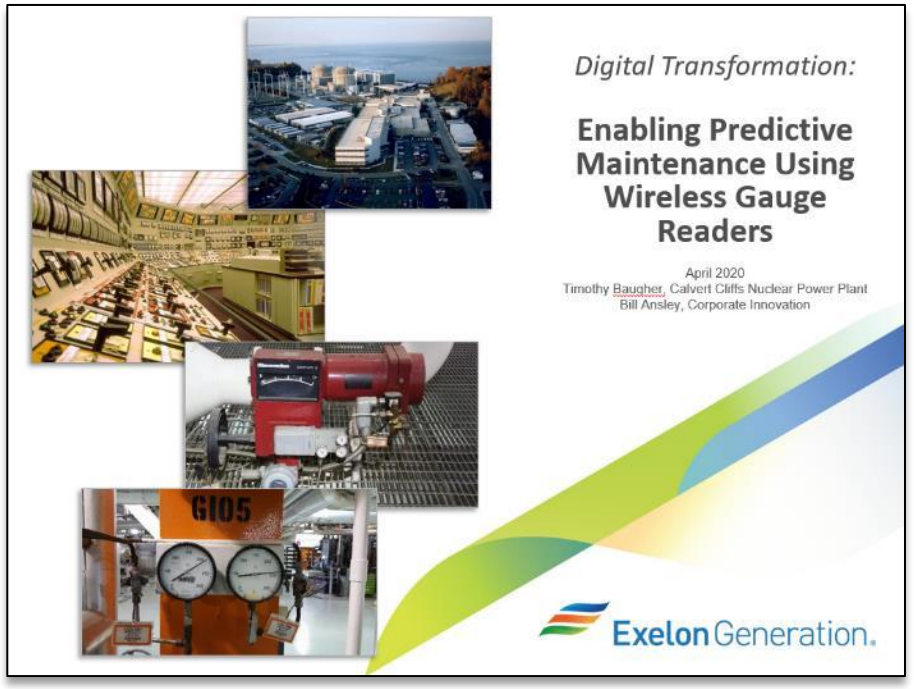
a) About 1,300 WGR's deployed at six Duke plants (fleetwide).

b) Points identified by operators and engineers – obtain more frequent readings, get history to understand issues

c) Augments/replaces daily rounds - 2% daily operator time savings documented at Duke Oconee

Fault Detection – Exelon/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.



Condition Based Maintenance + ALARA – Exelon 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.

Environmental Compliance – 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)

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Fault Detection – NextEra Turkey Point

- Turkey Point identified Pump Failures as a key contributor to unplanned downtime.
- Pump bearing temperatures are good predictive indicators of impending failure.
- Existing temperature monitors have only manual indicators.
- Cypress installed WGR's to capture data to send to PI Historian, Advanced Pattern Recognition algorithms, to enable early fault detection and correction.

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Personnel and Equipment Safety – Southern

- Monitoring SF6 Gas for switchyard and substation circuit breakers
- SF6 gas used for arc quenching
- Gas leak can cause unintended dangerous arcing
- SF6 is highly toxic, do not want to send people to detect leaks
- WGR's can be used to retrofit existing circuit breakers for remote monitoring without risk of introducing leaks

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Thermal Performance – Duke Harris

- Monitor and detect shutoff valve leakage via pipe wall temperature
- Undetected leaking shutoff valves can degrade thermal performance
- Use WSTM to monitor pipe wall temperature downstream (and if needed also upstream to get delta temperature)
- Non-invasive clamp-on thermocouples – up to 500 deg F
- Electronics/wireless module connected by thermocouple wire – up to 500 ft distance

Deployed at Duke Harris Nuclear Plant

Transfomer Fault Detection – Exelon Calvert Cliffs

- Connect legacy transformer trace gas monitoring systems to PI Historian.
- Allow old ModBUS IP protocol to communicate and conform to latest cyber security requirements.
- Enable automated fault detection.

GE
Digital Energy

Intellix* MO150 specification sheet

Description

The Intellix MO150 is an intelligent, dynamic transformer monitoring system designed to provide comprehensive monitoring and interactive condition diagnostics for oil-insulated transformers used by electrical utilities and large industries.

Functionality

The Intellix MO150 system is designed to collect, process, analyze and interpret critical operations on data obtained from various sensors. It incorporates onboard intelligence, which utilizes the monitored transformer's characteristics along with real-time measurements to automatically compute on-line state-of-the-art mathematical transformer models based on IEEE® or IEC® standards. The on-line models of the system include:

- MVA model which computes apparent power on primary, secondary or tertiary winding
- Winding hot-spot temperature model which computes the hot-spot temperature of each winding where load current is measured
- Moisture in the thin conductor insulation and in the barrier insulation which computes the moisture content of each
- Insulation aging which computes aging acceleration factor from IEEE or IEC guidelines
- Tap changer thermal model which computes temperature difference between the LTC tank and main transformer oil tank
- Tap changer position tracking model as the tap position transitions are recorded and tracked
- Cooling control for management and operation of the transformer cooling system
- Cooling efficiency which monitors actual efficiency of the cooling system

Electronic Controller

Microprocessor based
- Watchdog
- Clock
- Memory storage
- More than 3700 historical alarms and events
- More than 6900 historical service logs (once per day)
- More than 100 days of short term logging (15 min interval)

Components
- Basic embedded software
- Backlit graphic LCD display: 128 x 66 pixels; seven lines of 20 text columns
- Membrane keypad with eight functions: up, down, left, right, escape and three interactive keys
- Four LED indicators: power, "System OK," Alarm One and Alarm Two
- Internal temperature controlled

Communications
- Local serial RS-232 link; connector type DB-9M; dielectric withstand: 1500 V RMS
- RS-485 port
- Remote communication via LAN and modem

Inputs and Outputs

Analog Inputs

Quantity: eight inputs, dielectric withstand: 1500 V RMS configurable to the following two options:
- RTD input; model PT-100; range: 0-270 Ω; accuracy: ± 0.15 Ω
- 4-20 mA isolated input (active/passive); wetting: 24 Vdc; maximum load: 40 mA; maximum input impedance: 220 Ω; accuracy: ± 0.01 mA

AC Analog Inputs

Quantity: five inputs, dielectric withstand: 2000 V RMS; input impedance: 150 Ω
- Three inputs for transformer winding currents H, X and Y (clamp-on CTs 50 mA)
- Two inputs for fan group current

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Cypress network:
Open System to Integrate with 3rd LoRaWAN sensors

Integration of 3rd Party LoRaWAN devices

MultiTech Reveal™ Wireless Proximity Sensors

MultiTech Reveal™ LoRaWAN Wireless Proximity Sensors detect contact between two wires, proximity detection with a magnet, range with an ultrasonic signal, while the Reveal UltraSonic Level Sensors provide high accuracy proximity detection and ranging in air.

MultiTech Reveal™ Wireless Push Button Sensors

The MultiTech Reveal™ LoRaWAN Wireless Push Button Sensor transmits on a button press event. They can be used as a panic button wearable device, personal emergency response system (PERS), remote control or other remote push button applications. When the button is pressed, an alert is sent to the wireless network.

MultiTech Reveal™ Wireless Movement Sensors

MultiTech Reveal™ LoRaWAN Wireless Movement Sensors use an ultra sensitive internal accelerometer to detect movement of a critical asset. When movement is detected that exceeds a certain threshold, an alert is sent over the wireless network. Reveal Tilt Sensors detect transitions between horizontal and vertical orientation, as well as reporting the angle of the tilt.

MultiTech Reveal™ Wireless Leak Detection Sensors

MultiTech Reveal™ LoRaWAN Wireless Leak Detection Sensors use a water probe to detect the presence of water or other liquids. When the presence of water or another liquid is detected, an alert is sent over the wireless network to prevent a potentially catastrophic event.

- Integrate devices with Cypress Gateway and GBC
- Same wireless network infrastructure
- Same cyber security approval
- Same OSI PI connectivity

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Integration of 3rd Party Sensors

3rd party LoRaWAN sensor

Enclosure in Field

Blue Box

CAT 5
UDP

Green Box

Plant Wi-Fi or Ethernet (L2 Network)

Connection via RESTful API, OPC UA, or OPC DA

OSI PI Historian

3rd Party App

Web Application Clients HTTPS using browser

Laptop

Smartphones/ Tablets

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Integration of 3rd Party IP Cameras

3rd party
IP camera

Ethernet

Green Box

Plant Wi-Fi or Ethernet (L2 Network)

Connection via RESTful API, OPC UA, or OPC DA

OSI PI Historian

3rd Party App

Web Application Clients HTTPS using browser

Laptop

Smartphones/
Tablets

Reading Sight Glasses, Vertical Indicators (Q2 2023)

- 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
- Same GBC infrastructure
- Same cyber security approval
- Same OSI PI connectivity

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