Title

Non-Invasive Digitization of Existing Nuclear Power Plants

Contacts

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Abstract

Most existing nuclear power generation plants entered service over 30 years ago[1], before the widespread adoption of digital instrumentation and automation. Compared with recent plants such as Vogtle 3 & 4 (part of the Southern Company fleet) which have over 20,000 digital data points per reactor, older plants such as Hatch (also part of Southern's fleet) have only ~2,000. Plant Hatch relies on operator rounds to manually gather data twice per day, and only for a small subset of process parameters.

These data points (pressure, flow, temperature, level etc.) provide visibility to plant processes and asset health. Newer plants can automatically collect this data and can use it to automate fault detection and reduce unplanned downtime, improve operator efficiency, optimize generation efficiency, enhance safety, and reduce radiation dosage rates for workers. In comparison, older plants have much lower visibility and must contend with higher operator workload, more frequent unplanned downtime, and higher maintenance costs.

Although the digitization of existing plants is a widespread effort, it is often expensive and disruptive to undertake. Traditional instrumentation and control solutions typically require lengthy engineering reviews, costly installation labor, and can only be implemented during outage periods. Installation requires invasive procedures including cutting pipes, chemistry analysis, running power and signal wires, cybersecurity measures, civil and mechanical engineering reviews etc.

However, recent non-invasive digitization technologies can be installed in 10 minutes with minimal engineering effort and no disruption to plant operations. These are lightweight, wireless, battery-operated devices that can be attached to existing manual instrumentation in less than 10 minutes. They minimize cybersecurity concerns because they are "air-gapped" by design and do not have contact with

plant processes. The cost of these non-invasive solutions is less than 20% of the cost of traditional approaches.

Over the past 18 months, Plant Hatch has digitized over 300 points with no disruption to plant operations, at a fraction of the cost of conventional approaches. This effort has enabled the deployment of new operator dashboards and processes to improve operator shift efficiency and has helped to detect faults to avoid generation losses.

1. Reference: https://www.visualcapitalist.com/how-old-are-the-worlds-nuclear-reactors/

Background and Objective

Date of most recent deployment: July 9th, 2024

What is the objective of the work being done?

To digitize and automatically collect plant process information (pressures, temperature, flow, level etc.) which is collected manually today.

Program objectives:

1) Improve operator efficiency - augment manual rounds, create "Rounds Dashboard" to improve operator trending capability
2) Improve predictive fault detection
3) Enable Condition Based Maintenance
4) Reduce radiation dose during rounds and troubleshooting - ALARA
5) Improve troubleshooting turnaround time

Where in the facility did it take place, and what were the conditions?

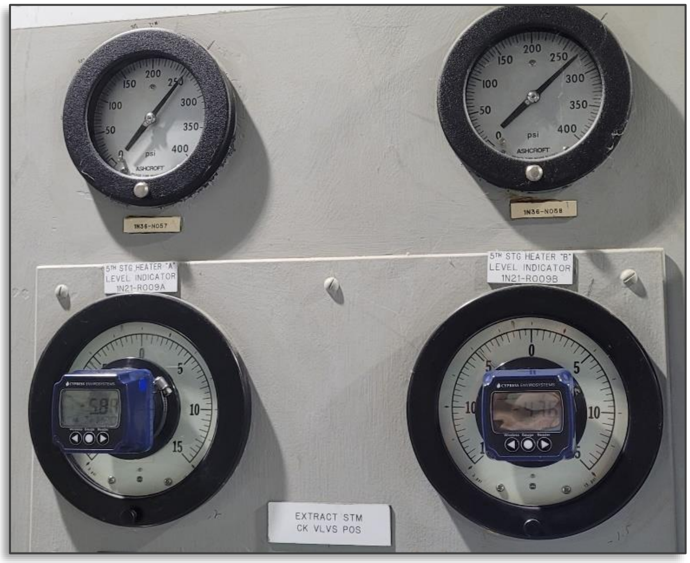
At Plant Hatch (GE BWR-4), Unit 1 and Unit 2 Turbine Buildings, all elevations. Installed during normal operations (no downtime, no outage period).

Describe challenges that led to the consideration of the specific solution.

Nuclear plants built in the 1970's and 1980's were not digitized, with most data collected manually by operator rounds. Compared with new plants (e.g. Vogtle 3 and 4, >20,000 digitized points), older plants like Hatch have much fewer digitized data points (~2,000). The relative lack of remote monitoring capability means that the plant has higher operational cost, more avoidable downtime, and less efficient generation.

Conventional digitization technologies are invasive, requiring extensive engineering design work and maintenance out-of-service time to install. In comparison, non-Invasive solutions take only 10 minutes per point vs. weeks, and cost less than 20% as much as conventional solutions (Figure 1).

Figure 1 – Non-invasive digitization solution for manual gauges



If applicable, describe how this work was completed previously

Operators collect process data via manual rounds, twice per day. The data is recorded but requires manual trending by operations or engineering to detect degrading performance. Automated predictive fault detection was not employed due to an insufficient amount of data captured and trended. In contrast, the new solution improves trending resolution by automatically capturing and trending data every 15 minutes, suitable for use by Advanced Pattern Recognition fault detection models.

Figure 2 – Manual Data Collection via Operator Rounds (typical)

Deployment Details

Describe the solution selected and the bases / criteria for the selection.

Criteria for solution:

- Augment manual gathering of plant process data by operators
- Ability to digitize analog gauges (pressure, temperature, flow, level) and analog instrumentation
- Non-invasive - does not require any disruption to plant operation
- No cutting pipes, no wetted parts, no leak checks, no running wires, minimal EMI field
- Minimal labor to install - 15 minutes or less per data point
- Lightweight, low energy battery operated - minimal engineering review and approval
- Can deploy in Radiologically Controlled Areas - up to 25 mrem/hr
- Compliant with nuclear plant Cybersecurity requirements.
  No physical contact with plant processes.
- Compatible with existing plant Historian database and data visualization system.
- Not considered Critical Data Asset (CDA).

Solution Selected:

- Cypress Envirosystems Wireless Gauge Reader and non-invasive monitoring solution suite. (Figures 3, 4, 5)

Figure 3 – Non-Invasive Wireless Gauge Reader

- "Electronic Eyeball" reads gauges and numeric indicators and transmits readings wirelessly
- Already approved and installed in over 30 nuclear power plants
- 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

Figure 4 – Cybersecurity approved in-plant data collection

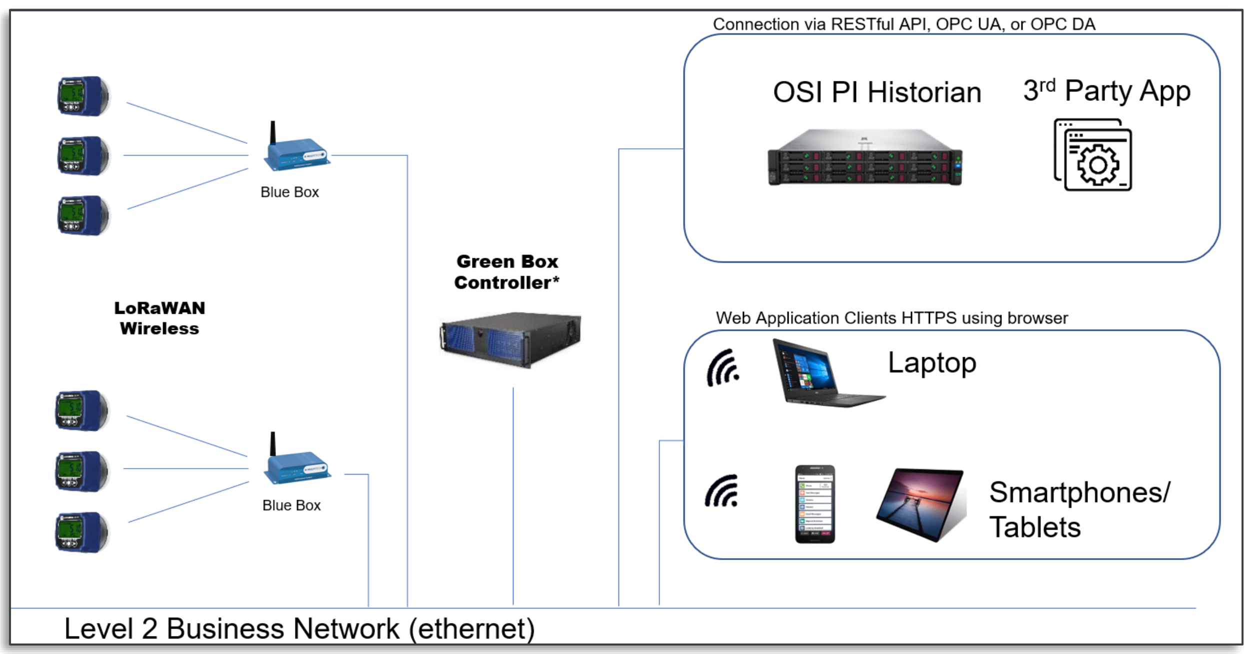


Figure 5 – Installation at Hatch - Operating Nuclear Power Plant

Is the solution commercial-off-the-shelf or customized?

The solution is a commercial off the shelf product. First availability was in 2008. First deployment in a Nuclear Plant in 2010. (Figure 6)

Figure 6 – Deployments at North American Nuclear Power Plants

WGR Deployments – Nuclear Generation

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

* Pending Installation

Describe preparatory work; for example, risk analysis, contact with regulator, mockup tests, destructive tests, verification & validation, etc.

- Selecting data points:
  - Select data points which are material to plant performance, and which can benefit from more frequent data collection and analysis
  - Select data points which can help reduce the workload and improve operator efficiency
- Ensure compatibility with existing operator rounds - must allow existing tasks to be completed
- Start with non-Safety Related points, but with capability to expand later to more applications
- Tested against plant cybersecurity standards - connected to Level 2 business network
- Reviewed for compliance with EPRI / NRC guidelines for Electromagnetic Interference
- Reviewed prior deployments at other nuclear plants for Operational Experience
- Reviewed product against civil engineering impact (weight, torque), and fire loading impact (plastic content)

Consider including a risk portfolio for various options and how the risks were addressed.

Portfolio criteria:

The following risks were identified during the review of the proposed solution:

- Impact to Safety Related equipment
- Impact to existing Seismic Analysis
- Impact on existing operator rounds and monitoring capabilities
- Impact to Plant Configuration Control

The impacts to Safety Related equipment and existing Seismic Analysis were addressed by taking a phased approach to deployment.

- Phase 1 was a limited deployment on non-safety related and non-seismic components to validate the technology.
- Phase 2 was an expansion of non-safety related and non-seismic components in all elevations in both Turbine Buildings.
- Phase 3 will deploy the technology in safety related and seismic areas of the plant. The engineering analysis to support this deployment is in progress.

The impact to existing operator rounds and monitoring capabilities were addressed by utilizing the appropriate mounting techniques (ultra slim mounts, flip up mounts, etc.) to minimize the impact to traditional monitoring techniques. (Figure 7)

Figure 7 – Ultra Slim and Flip-door Mounting Improves Operator Visibility

The impact to configuration control was addressed through the development of an Operations Department Instruction that outlines the limitations for installation/use of wireless gauge readers and maintains a list of where each reader is installed in the plant. (Figure 8)

Figure 8 – Operations Department Instructions

Southern Nuclear

HATCH
Unit C

DI-OPS-96-1222

Control of Wireless Gauge Readers

VERSION 1.1

Special Considerations:

Applicable to HNP

PROCEDURE LEVEL OF USE CLASSIFICATION PER NMP-AP-003	
CATEGORY	SECTIONS
Continuous	NONE
Transient Response	NONE
Reference	ALL
Information	NONE

Approval: Hank Strahley (Approved By) 08/15/23 (Date)

Effective Date: 01/09/24

OPERATIONS
Responsible Department

The following benefits were identified during the review of the proposed solution:

- Higher resolution of trending data collected
- Automatic data collection and monitoring

Data is being collected, logged and trended every 15 minutes versus every 12 hours utilizing the wireless gauge reader technology which gives the operators and engineers the ability to identify degrading component performance earlier. Early identification allows corrective actions to be taken before the condition impacts plant operations.

Automatic data collection and monitoring reduces operator workload thus freeing up resources to perform other tasks such as system tag outs, Surveillance and Preventive Maintenance activities. An additional benefit to automatic data collection is reduced radiation exposure to operating personnel due to less time being spent in the Radiologically Controlled Area (RCA).

Who operated the system/s, device/s, etc., and what other personnel were involved?

For Plant Hatch, Operations is the main owner of the solution. Operations uses the system to monitor and trend system/component performance and is also responsible for minor maintenance tasks such changing batteries.

Chemistry and Radiation Protection and Engineering are secondary users. Chemistry uses the system to monitor condenser hot well conductivity and sodium concentrations for early detection of a condenser tube leak. Engineering uses the system to monitor system health and perform troubleshooting activities.

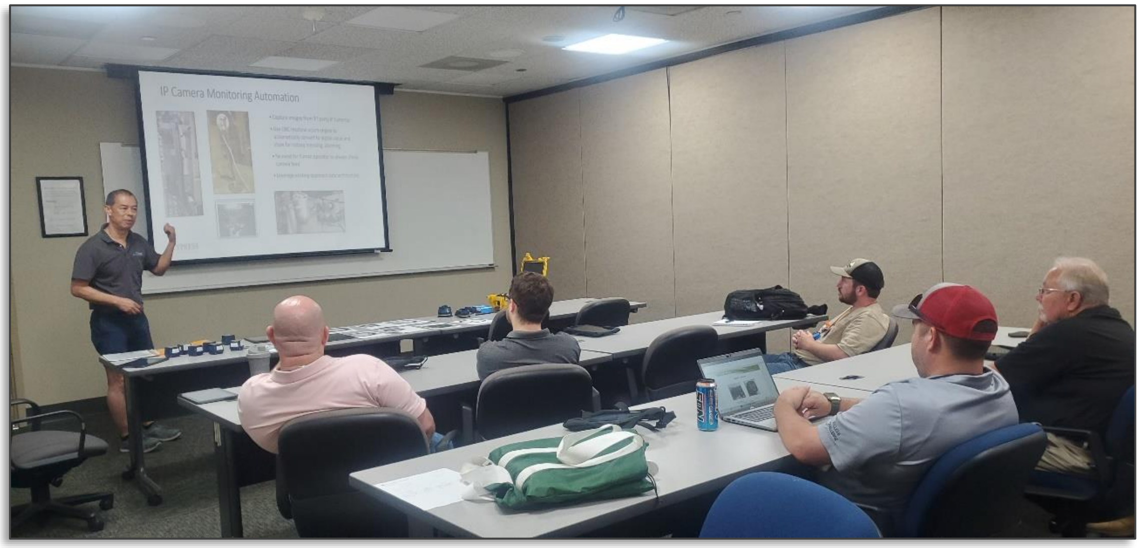
Maintenance support is performed by Instrumentation and Control (I&C) team and the Information Technology (IT) team. I&C performs reader installations and calibrations. IT maintains the interface between the readers and the network which allows data transfer to the business LAN.

Was there / is there an existing team trained to do the work?

Yes, vendor provided user training as well as for training for initial installation, ongoing maintenance

- Total of 35 people were trained to date - Operators, I&C, IT, FIN (Fix-It-Now) Team, Radiation Protection, and Chemistry (Figure 9)
- Training included a “Train the Trainer” session. Plant Hatch is currently self-sufficient in the ability to train on installation, calibration and on-going maintenance.

Figure 9 – Classroom Bench Top Training Augmented by In-Plant Actual Installation Training



Did the work deviate from the plan? If so, please share details.

The work did not deviate from the plan.

- Phase 1 preparation took 6 months, including walkdowns by Operations, Maintenance and Information Technology, Work Order preparation, initial communications to the affected stakeholders and material preparations.
- Phase 1 Installation and commissioning (100 devices) was completed in one week with support from vendor.
- Phase 2 Planning required 3 months.
- Phase 2 Installation and commissioning (200 devices) was completed in one month using plant personnel with minimal vendor support on-site.
- Phase 3 planning is now underway.

Summary/Result

Describe the extent to which the solution addressed the original objective, overcame identified challenges, etc.

Performance against program objectives:

1. Improve operator efficiency - augment manual rounds, create "Rounds Dashboard" to improve monitoring and trending capability. (Figure 10)

    - Reduce 2 hours per shift for manual data collection - free up operator time for other tasks
    - Rounds Dashboard created - operators use at beginning of shift to help optimize shift activities by allowing a quick review of trends and out of spec readings

2. Improve fault detection

    Within the first 3 weeks of installation, detected malfunction of pneumatic valve controller for stator cooling water flow. A faulty valve controller created temperature oscillation in cooling water, the fault was undetectable by visual inspection and instantaneous information gathering but was detected due to the higher resolution data gathering. Early fault detection and with high resolution monitoring, the plant avoided loss of generation capacity and avoided 2 man-hours per day for operator manual workload to read gauges and manage issue.

3. Enable Condition Based Maintenance

    - Monitoring of filters
    - Monitoring of rotating equipment
    - Monitoring of air operated equipment

4. Reduce radiation dose - ALARA

    - Less time spent monitoring and data gathering directly equates to dose savings (especially in Boiling Water Reactor plant).

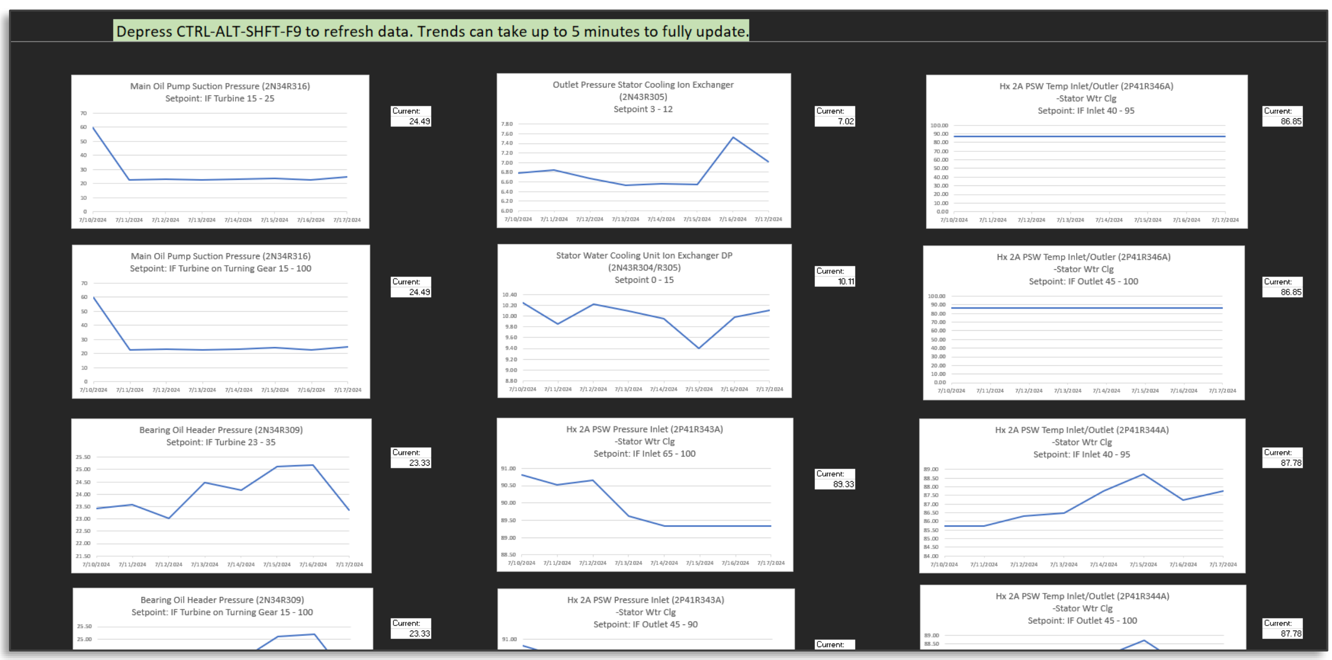
5. Improve troubleshooting turnaround time

    - Two crash carts created with inventory of non-invasive readers.
    - Can respond to emergent issues to start collecting troubleshooting data within 30 minutes (conventional data collection would take weeks to identify solution and obtain approval to install) (Figure 11).
    - Adjustable sample rate for emergent monitoring – as fast as one sample every seven seconds.

Figure 10 – Operator Rounds Dashboard

2 If the cell to the left is not green, then AT THE SAME TIME, press and release "Ctrl", "Alt", "Shift", and "F9" to refresh the data.

Rec/Sta(#)	System	MPL	Description	Current Value	Frozen Gauge Check	NOTES (System OOS/CR# on Gauge)
25	Turbine	2N34R316	Main Oil Pump Suction Pressure	SAT	SAT	
508	Turbine	2N34R316	Main Oil Pump Suction Pressure (IF on Turning Gear)	SAT	SAT	
26	Turbine	2N34R309	Bearing Oil Header Pressure	SAT	SAT	
509	Turbine	2N34R309	Bearing Oil Header Pressure (IF on Turning Gear)	SAT	SAT	
27	Turbine	2N34R315	Operating Oil Pressure	SAT	SAT	
510	Turbine	2N34R315	Operating Oil Pressure (IF on Turning Gear)	SAT	SAT	
111	RFPT	2N34R317	RFPT Oil Conditioner Pump Discharge Pressure	SAT	SAT	
112	RFPT	2N34R324	RFPT Oil Conditioner Discharge Pressure	SAT	SAT	
113	RFPT	2N34R317 - 2N34R324	RFPT Oil Conditioner Polishing Filter DP	SAT	SAT	
162	SWC	2N43R304	Inlet Pressure Stator Cooling Ion Exchanger	SAT	SAT	
163	SWC	2N43R305	Outlet Pressure Stator Cooling Ion Exchanger	SAT	SAT	
164	SWC	2N43R304 - 2N43R305	Stator Water Cooling Unit Ion Exchanger DP	SAT	SAT	
171	SWC	2P41R343A	Hx 2A PSW Pressure Inlet	SAT	SAT	
172	SWC	2P41R345A	Hx 2A PSW Pressure Outlet	SAT	SAT	
173	SWC	2P41R345B	Hx 2B PSW Pressure Inlet	SAT	SAT	
174	SWC	2P41R343B	Hx 2B PSW Pressure Outlet	UNSAT	SAT	
175	SWC	2P41R346A	Hx 2A PSW Temp Inlet	SAT	SAT	
176	SWC	2P41R344A	Hx 2A PSW Temp Outlet	SAT	SAT	
177	SWC	2P41R344B	Hx 2B PSW Temp Inlet	SAT	SAT	
179	SWC	2N43R308	Generator Filter Inlet Pressure	SAT	SAT	
180	SWC	2N43R307	Generator Filter Outlet Pressure	SAT	SAT	
181	SWC	2N43R308 - 2N43R307	Generator Filter DP	SAT	SAT	
187	SJAE	2N22R327A	SJAE Drain Tank 5A Pressure	SAT	SAT	
188	SJAE	2N22R327B	SJAE Drain Tank 5B Pressure	SAT	SAT	
189	H2 Stator Clg	2N43R315	Machine Gas Pressure	SAT	SAT	



Credit: Operator Dashboard developed by J. Plumb, Operator at Duke Energy, Oconee Nuclear Plant

Figure 11 – Emergent Issue Crash Cart

Supporting Information and Media

Attachments:

1. Procedure: Control of Wireless Gauge Readers – Southern Nuclear Hatch Nuclear Plant
2. Procedure: WGR Deployment Checklist – Southern Nuclear Hatch Nuclear Plant
3. Nuclear Information Technology Strategic Leadership (NITSL) Presentation: Non-Invasive Digitization of Existing Nuclear Power Plants
4. EPRI Configuration and Demonstration Report
5. EPRI Nuclear Plant Modernization Technology Assessment

Video illustrating non-invasive mounting:

https://www.cypressenvirosystems.com/files/tmp/Flip%20Door%20Movie%20-%20V1.mp4

IAEA
International Atomic Energy Agency

International Network on
Innovation to Support Operating Nuclear Power Plants (ISOP)

Innovation Award
on
Other Innovations
is presented to

Mr Harry SIM

Non-Invasive Digitization of Existing Nuclear Power Plants

Cypress Envirosystems, Inc./USA

17 September 2024

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Team Leader Nuclear Power Plant
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