AI Enabled Predictive Maintenance Digital Twins for Advanced Nuclear Reactors

GEMINA

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Predictive Maintenance Digital Twins

Summary

Program Impact

AI-enabled predictive maintenance to ↓ O&M labor costs from $15/MWh to $3/MWh in an Advanced Nuclear Reactor

Program Targets

<table>
<thead>
<tr>
<th>Metric</th>
<th>From</th>
<th>To</th>
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</thead>
<tbody>
<tr>
<td>Automation ↓ labor costs</td>
<td>None</td>
<td>Automated workorders ... ↓ Planning staff Online calibration ... ↓ Tech and admin staff</td>
</tr>
<tr>
<td>Predictive Maintenance ↓ labor &amp; mat'l</td>
<td>Alarms</td>
<td>↓ Forced outages &amp; trips ... AI-driven predictive algorithms → ↓ Labor headcount</td>
</tr>
<tr>
<td>Trust</td>
<td>Human</td>
<td>Humble &amp; explainable AI ... quantify uncertainty to establish trust in the models &amp; encourage automation</td>
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Technology Summary

- Reactor Operations – Physics-informed machine learning, sensor optimization
- Reactor Health – Causal, humble & explainable AI for predictive maintenance
- Decision Making – Autonomous risk-informed decisions for reconfiguration & maintenance
Team

GE Research
- Predictive Maintenance Digital twins
- Humble AI for trust & UQ for digital twins
- Probabilistic Reasoning
- Workorder Automation

Oak Ridge National Lab
- I&C Autocalibration,
- Flow-loops for cyber-physical validation,
- Risk-informed decisions,
- Regulatory Analysis

Univ. of TN Knoxville
- Predictive Analytics for Nuclear plant Systems,
- Reconfiguration
- Regulatory Analysis

GE Hitachi Nuclear
- SMR OEM,
- BWRX-300 Reactor Design,
- Reactor Simulations
- FMECA and PRA
- Maintenance Cost Analysis
- WO automation
- Demonstration on existing BWR fleet

Exelon Energy Corp
- Utility Operator,
- Operational and Regulatory Exp.
- Maintenance Cost Analysis
- WO automation
- Demonstration on existing BWR fleet

GE Research
1. Development of operational and health digital twins for
   • High value plant systems/components (low hanging)
   • Reactor core critical components (challenging)

2. Demonstration of automation
   • Online sensor calibration – use flow-loop HIL testbed
   • Work order automation – APM cloud deployments

3. Research to address gaps and challenges
   • Humble AI (challenging – technical development)
   • Risk, uncertainty & decision – (challenging – integration)

4. Analyses & Design
   • Opportunity to improve BWRX-300 design (OSP)
   • Cost reduction opportunities and entitlements in SMR systems
   • Regulatory needs and constraints
T2M

› Integrate PMDT technologies into GE Hitachi’s BWRX-300
› Demonstrate PMDT technologies on existing BWRs
› Actively participate and contribute to discussions on regulatory aspects of AI integration
› Collaborations with other projects