The Next Gen of Simulation: Engineering, Hydrogen and more.
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Agenda

• Integrated Simulation
• Hydrogen Production
• Steam Extraction
Nuclear Plant Case Study
Adding Value through Integrated Simulation

• **Background**
  - Unit 2 #3 Feedwater Heaters replaced in 2015, Unit 1 #3 Feedwater Heaters were replaced in Spring 2020.

• **Problem Statement**
  - After each replacement, a heater level swing of 2-3 inches every 5 seconds was observed in both units.
  - Condition Report remains open 5 years later despite repeated troubleshooting attempts to isolate and resolve oscillation issues.
  - Led to numerous package leaks and premature wear on valve actuators.
  - No changes were made to the FWH Control Systems.
Nuclear Plant Case Study
Adding Value through Integrated Simulation

- Collaboration with Thermal Performance Subject Matter Experts (SMEs) and simulation to model thermal kit to produce new insights.
  - Existing approaches are based on static conditions.
  - Simulation w/ JTopMeret allows for dynamic analysis at various power levels.

- Obtained additional plant data to model the detailed heater internal structure of volumes and, tube areas, etc.
Nuclear Plant Case Study
Adding Value through Integrated Simulation

• JTopMeret for heat exchanger thermohydraulics
• JControl for PI controller of normal and alternate/emergency drain valves
• Malfunctions
  - Leaking vapor into drain cooler from shell (different than vapor from low heater level)
  - Tube leaks (into shell)
  - Tube Plugging/fouling (increases DP/reduces flow on tube side)
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- Growth through collaboration

- JADE Operator Station
  - Created simple engineering interface to interact with model, change setpoints, output for drain valves, observe results
  - Linked data to spreadsheet to compare to heat balance reference values for analysis

- Used Automated Scenario Testing to enable engineers to graphically create and edit test/experiment scenarios (e.g. open/close vapor leak into drain cooler at designated intervals).
Nuclear Plant Case Study
Adding Value through Integrated Simulation

• Together, GSE Programs & Performance and GSE Systems & Simulation groups developed a high-fidelity model of the Feedwater Heater -> Reusable structure.

• After data input in the High-Definition FWH model, the behavior were surprisingly close to the design data through the Heater. Allowed “What-If” scenarios to be tested and automated.

• Facilitated GSE to provide additional insights and new value to the customer in decision making on future mods and troubleshooting the existing system.

• Led to additional services purchased by the customer, while in-progress on the initial engagement.

Differentiation through ONE GSE

Next Steps
- Engage in new scenario development as additional plant transient data is provide
- Apply and embrace hyper-model development as a practice
Nuclear Plant Case Study
Adding Value through Integrated Simulation

• Benefits and insights possible with high-fidelity simulation
  - Once modeled in GSE’s JADE JTopMeret software tool, operators can re-use the tool to enter or modify data and immediately see responses based on first principles.
  - Local controls were created for the Normal, Alternate and Emergency drain valves.
  - Malfunction created to mimic real scenarios that impact plant and equipment performance
    • Leaking vapor into the drain cooler from the shell (separate from any vapor that would go in from low heater level).
  - Tube plugging & fouling
    • Overall tube fouling to reduce heat transfer can be adjusted
  - Model boundary conditions could also be manipulated by setting the model pressure, temperatures and the boundary driver.
    • The simulation recalculate the inlet/outlet boundaries (extraction steam, drains, feedwater in/out).
Hydrogen Simulation
Hydrogen Production

Small Modular Reactor Pilot Project

- GSE is developing a model on an integral PWR to high temperature heat to produce hydrogen

- Simulating high fidelity unit operation equipment and chemical components using superheated steam and electricity routing to a High Temperature Steam Electrolysis (HTSE) system

- Deliverable will be used to inform engineering analysis and cost evaluation

- Collaboration with Idaho National Laboratories (INL) researching high-temperature steam electrolysis (HTSE) for large-scale H2 production using solid-oxide electrolysis cells (SOECs)
GSE Hydrogen Service Offerings

SERVICES FOR A NEW NUCLEAR ECONOMY

GSE is uniquely positioned to provide services that help utilities evaluate and implement their hydrogen production capability, including:

- Virtual Commissioning & Simulation
- Engineering Program Impact
- Thermal Performance & Analysis
- Plant Procedures
- Design Engineering Support
- Training
- Expert Staff Services

GSE can play an even broader role in the clean Hydrogen story, aiding nuclear power plants as they consider the viability of a hydrogen revenue stream.
Steam Extraction
Steam Extraction

• **Background**
  - Growing need for new revenue sources for existing NPPs
  - Small modular reactor (SMR) needs for optimizing performance during load following and increasing revenue model
  - Growing market for Green Hydrogen

• **Initiatives**
  - Light Water Reactor Sustainability Program
  - Incorporation of Thermal Hydraulic Models for Thermal Power Dispatch into a boiling water reactor (BWR) plant simulator

• **Collaborating Organizations**
  - Idaho National Laboratory
  - University of Florida
  - GSE Systems & Simulation group
• **BWR Steam Extraction Model**
  - DOE desire to focus on BWR similar to previous work on PWR.
  - Obvious operating differences between PWR and BWR.
  - Evaluate locations of extraction lines and media.

• **Objective**
  - Tools to study feasibility to coupling existing NPP to industrial process plant
  - Focus on differences between PWR and BWR plant and how to integrate Thermal Power Dispatch (TPD).
  - Develop methods & procedures to safely maintain NPP at or near 100% while transitioning between TPD modes.
INL Thermal Power Extraction/Dispatch Models

• Case Study
  - Extract thermal energy from the power generation loop of PWR/BWR plants to be provided to an external industrial process user like a hydrogen plant
  - Simulations were performed to test the transient response of the BWR plant due to the diversion of steam from the main steam header to the Thermal Power Extraction Loop until a 15% reduction of electrical power was observed from the turbine.
  - Fully Integrated with Full-Scope GPWR (Generic PWR Simulator) GBWR (Generic BWR Simulator) with control/logic
Steam Extraction Model Diagram

• Project was to create a steam extraction loop, so that a portion of steam may be diverted from the plant turbine power loop to intermediate heat exchangers.

• The steam flow rate controlled by new pressure controller, to assist in maintaining a stable pressure in main steam header. (PWR used flow controller)
Steam Dispatch Model Diagram

• A second loop on the secondary of these intermediate heat exchangers circulates a process fluid for delivery of the thermal energy to the process user, hydrogen plant etc.
Results

• As steam flow increases in the XSL, flow through the turbine and feedwater heater systems decrease.

• Feedwater temperature entering the reactor to decrease.

• The lower reactor void fraction increases neutron moderation.

• Feedwater temperature decreases from 423 °F to 409 °F, and the reactor power increases from 100% to nearly 102%.
Results

![Graphs showing feedwater temperature and reactor power over time. The graphs illustrate the variation of these parameters with time, with specific points marked for analysis.](image-url)
Additional Experiments & Future Actions

- Return Condensate from Extraction Steam Line to Feedwater Heaters vs Condenser (minimize waste of enthalpy and stressing FW heater system)
- Extract Steam from HP or LP turbines vs Main Steam Line
- Continue to improve system designs, improve control and safety systems, investigate additional systems to prevent impact of TPD operations on the plant
Other Examples

• WEC AP-1000 Haiyang
  - Steam extraction for use in District Heating
  - Turbine Extraction, lower pressure
  - Collaborating with WEC on modeling and controls

• SMR Use
  - Modeling both steam extraction and hydrogen plant
  - Potentially multiple designs:
    - Solid Oxide Electrolysis Cells
    - Electrolyzers
Summary

• GSE is adding value with simulation to solve engineering challenges through integrated project teams in simulation and thermal performance

• GSE has software, skills, and experienced staff members supporting behind-the-meter programs (Hydrogen Production) and Steam Extraction
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