INL/CON-22-67662-Revision-0

Presentation Deck A High Temperature Gas Reactor Integrated Energy System Using Energy Storage as a Buffer for Hydrogen Production

June 2022

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Changing the World's Energy Future

Idaho National Laboratory

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Prepared for the
U.S. Department of Energy
Under DOE Idaho Operations Office
Contract DE-AC07-05ID14517

INL/CON-22-02298

IES
Integrated Energy Systems

A High-temperature Gas Reactor Integrated Energy System Using Energy Storage as a Buffer for Hydrogen Production

ANS Conference Presentation

Prepared and Presented by:
Dr. Daniel Mikkelson

HYBRID

Presentation Agenda

1. HYBRID repository overview (5 min)
   a) HYBRID within FORCE
   b) Goals of modeling in HYBRID
2. Specific IES case (5 min)
   a) HTGR model
   b) HTSE model
   c) Two-tank SHS model
3. Results (5 min)
   a) Two tank system charging
   b) HTGR impact of modal operation

HYBRID within FORCE

- The Framework for the Optimization of ResourCes and Economics is developed at INL for economic analysis and optimization
- HYBRID is used to host appropriate physical modeling to identify economic constraints based on integrated simulation
- HYBRID will contain required economic data for FORCE analysis directly associated with the physical modeling efforts

HYBRID

- HYBRID is a collection of dynamic physical models written in the Modelica language to characterize
  - Ramp speed
  - Thermal and electrical integration of different processes
  - Creation of novel control schemes
  - Off-nominal system dynamics
  - Safety limitations based on control systems
- Adding parallel structured collection of steady-state models, reduced-order models, and economic data for enhanced integration within FORCE

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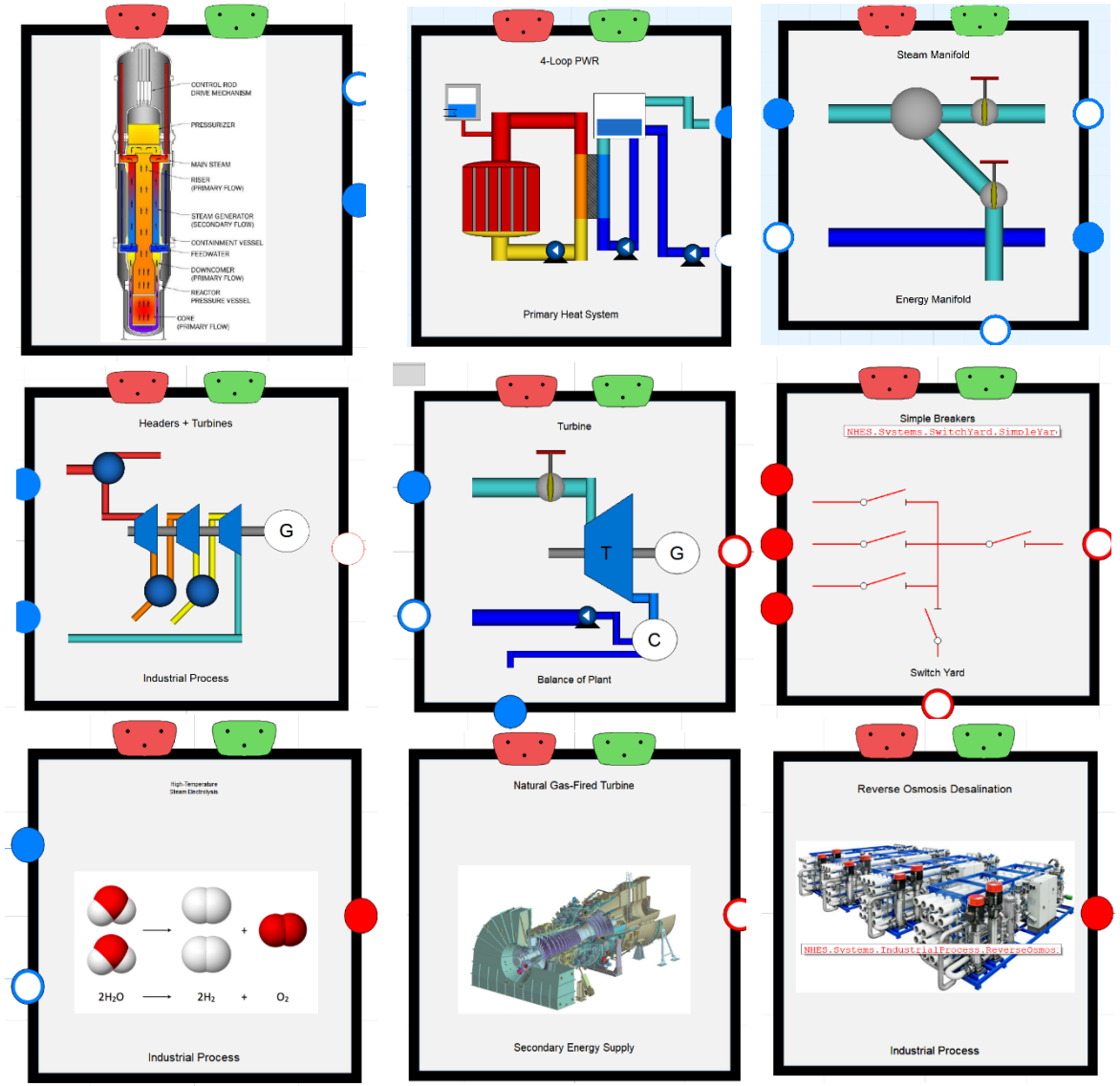
HYBRID - Dynamic

- Adaptable – Use of Modelica
  - Object oriented with standardized connections
  - Using FMI/FMU standard, external collaboration without transfer of sensitive proprietary data or recoding of models can be accomplished
  - Components can be “hot swapped” within code
    - Modelica was originally developed for the automotive industry as the language of choice for quick interchangeability: drive shafts, engines, transmissions, electronics, etc.

HYBRID Repository

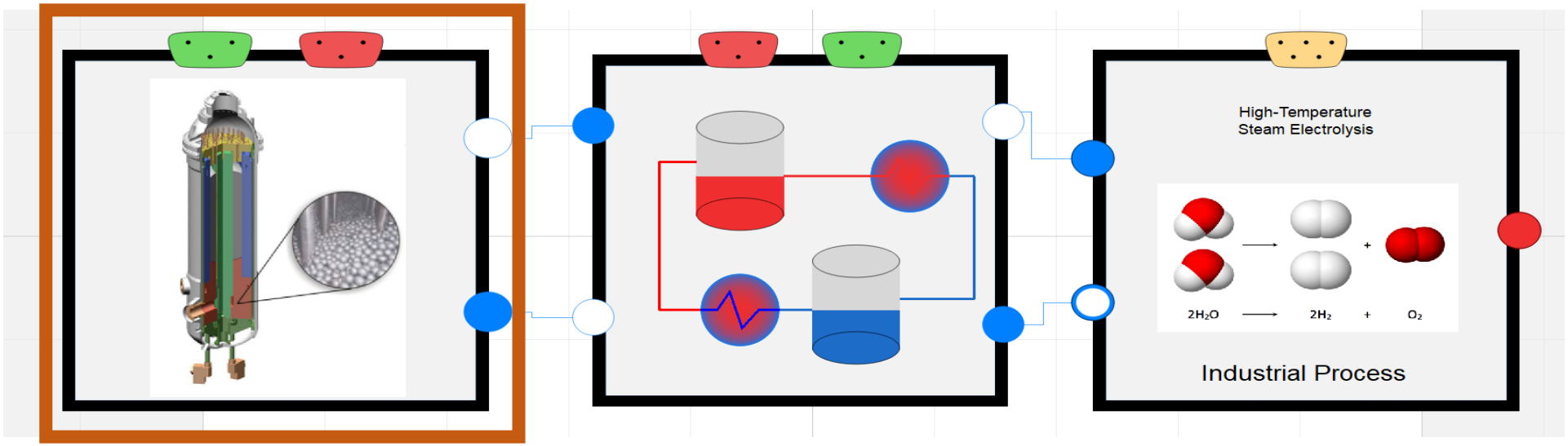


- Hybrid evaluates the feasibility of systems developed within FORCE and provides constraint data necessary for broader system evaluations
  - An ideal intermediary for determining
    - Integration design
    - Control methods
    - Ramp rate feasibility
    - Determination of off-design behaviors

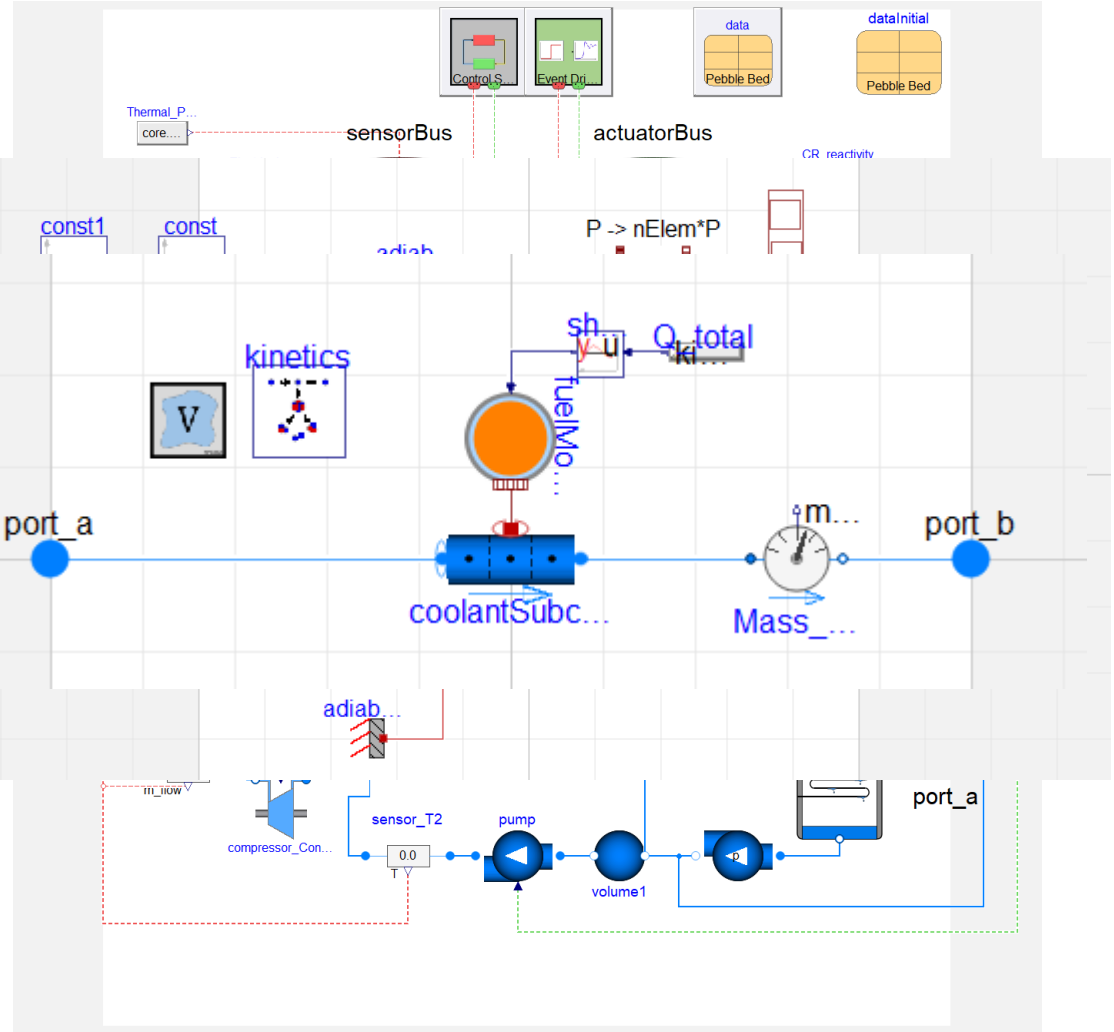
IES Integrated Energy Systems

HTGR-HTSE-IES

- IES containing three main subsystems:
  - Pebble bed Helium-cooled TRISO-fueled HTGR
  - Two tank sensible heat storage loop
  - HTSE Hydrogen production



HTGR-HTSE-IES



- HTGR has a pebble bed core with encapsulated TRISO fuel kernels
- Two stage Rankine cycle with bypass for feedwater heating produces electricity
- Bypass flow rate controlled downstream, removed at steam generator outlet

HTGR-HTSE-IES

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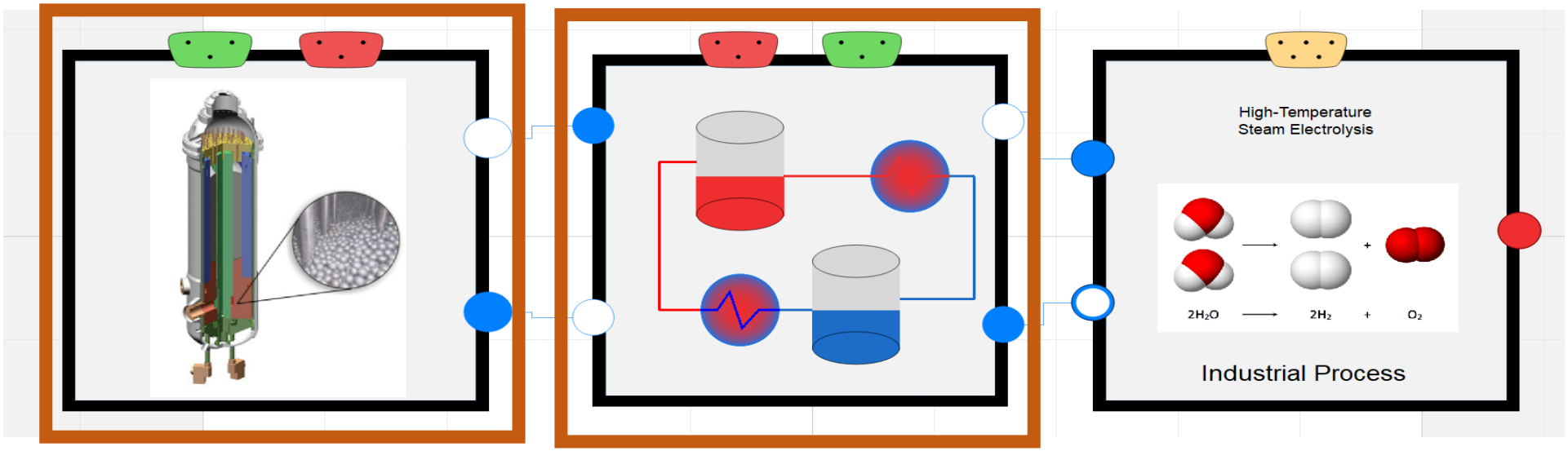
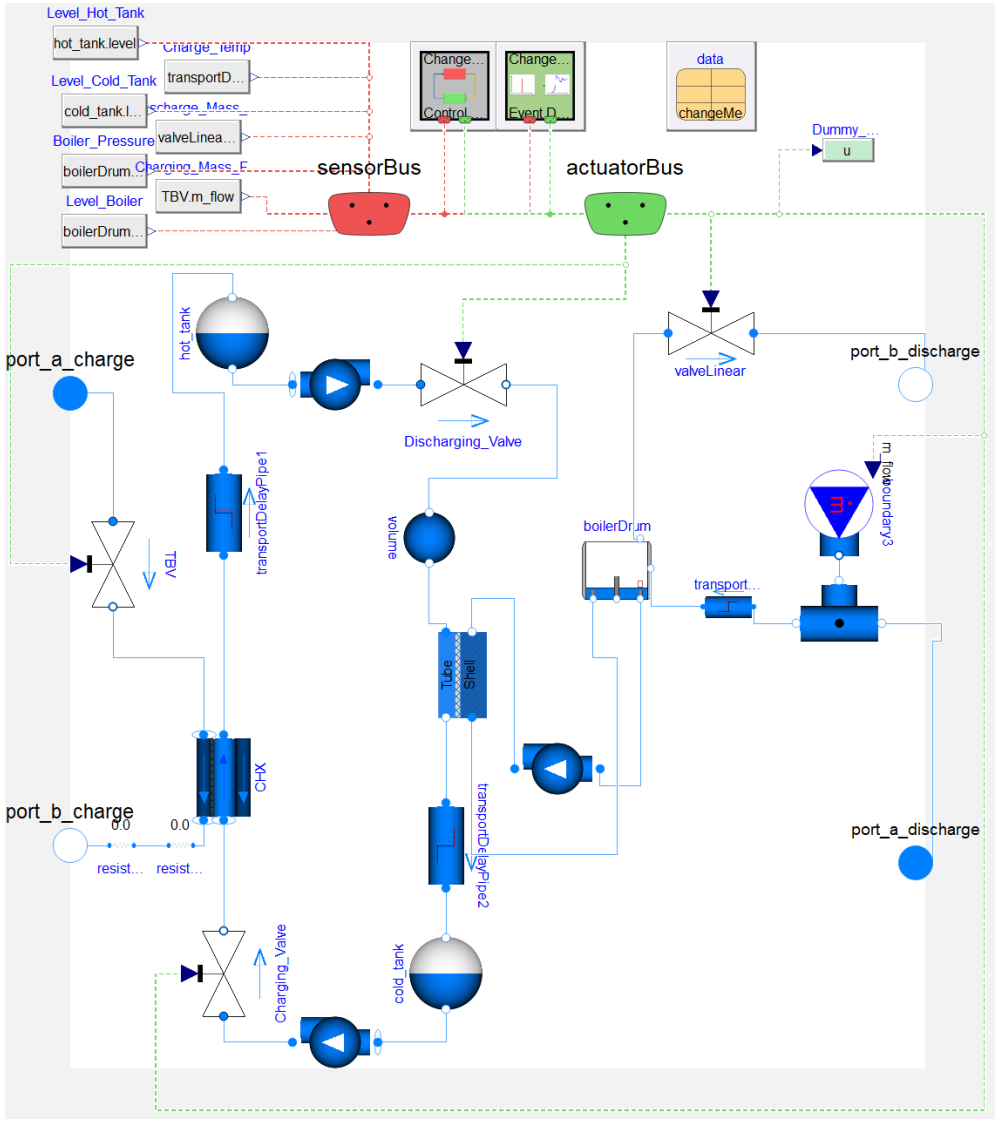


HTGR-HTSE-IES



- Two-tank thermal energy storage system
- Hot tank temperature controls charging mass flow rate
- Steam production demand controls discharging mass flow rate
- Steam production mechanism is application specific

HTGR-HTSE-IES

- IES containing three main subsystems:
  - Pebble bed Helium-cooled TRISO-fueled HTGR
  - Two tank sensible heat storage loop
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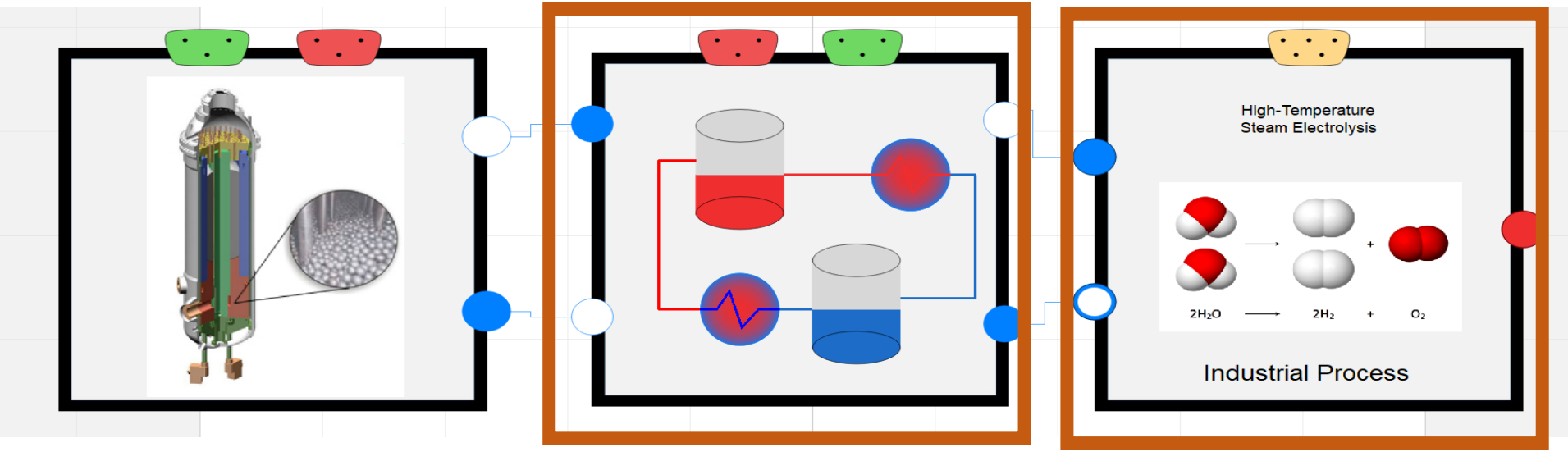
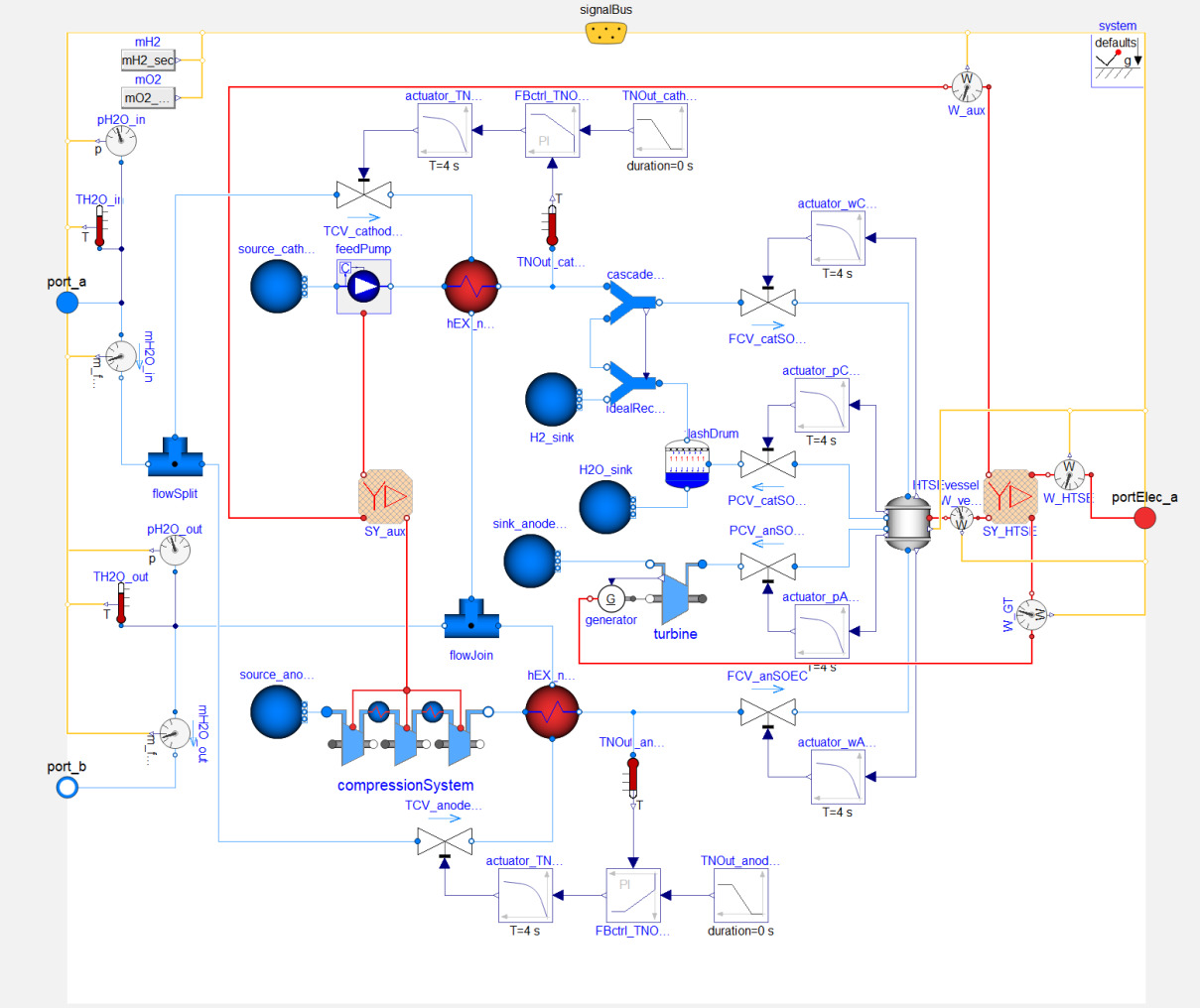


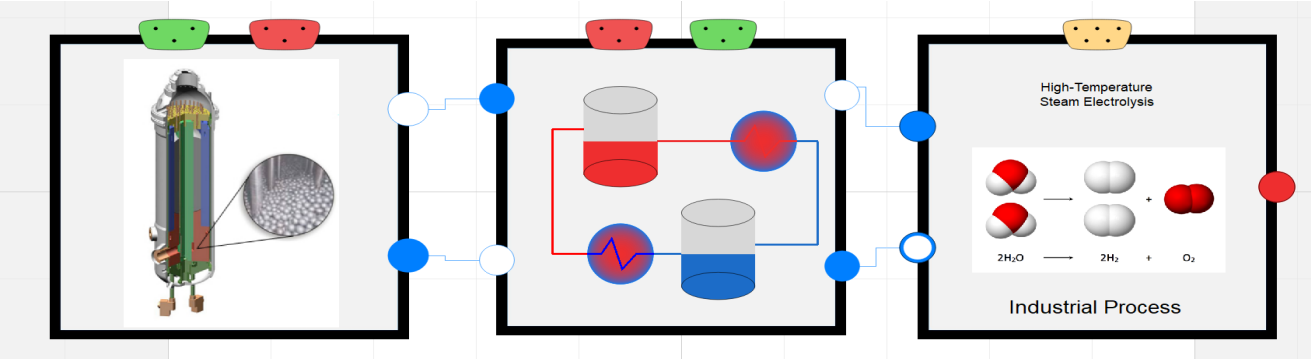
HTGR-*HTSE*-IES



- HTSE Hydrogen production plant using SOEC stack models
- Heating steam and electrical input connections required
- Can be readily altered to allow for Hydrogen storage addition

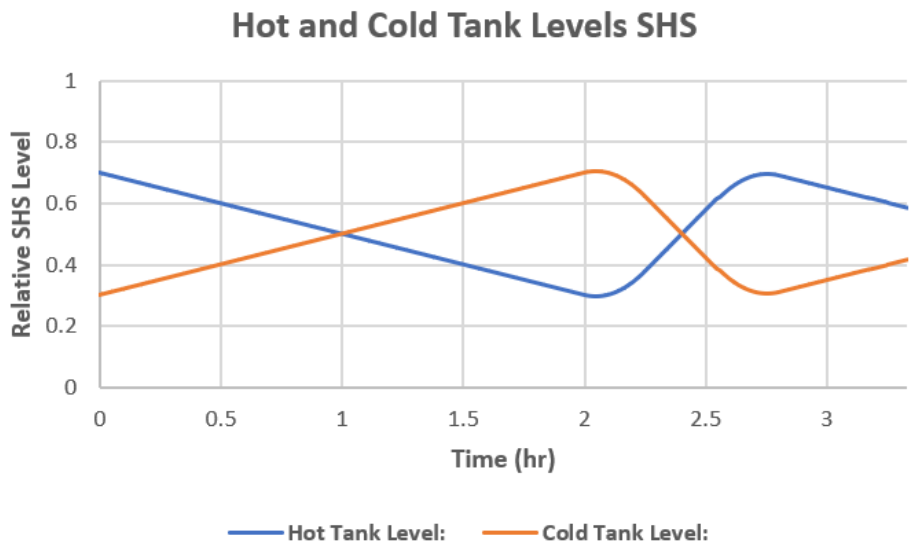
HTGR-HTSE-*IES*

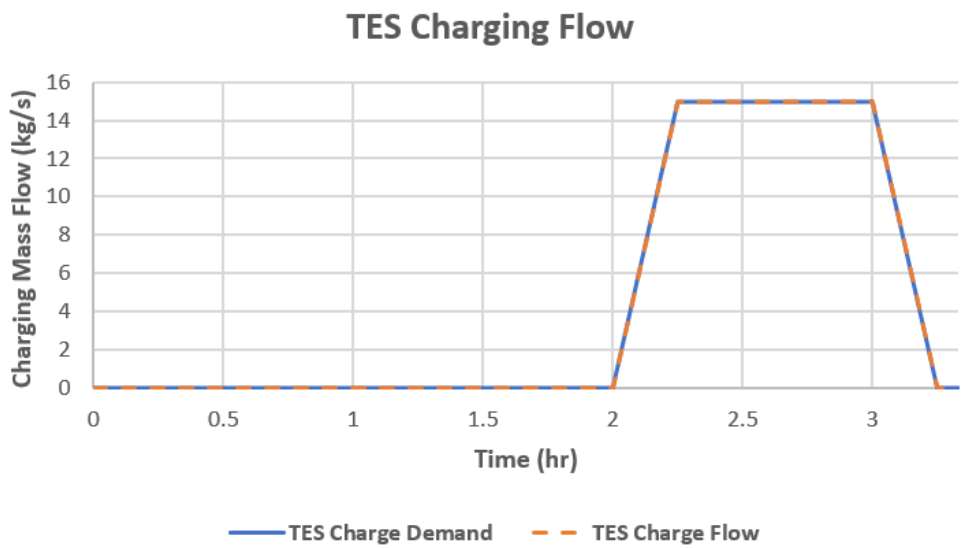
- Hydrogen production was held constant, so no additional controls were imposed on the system
- Two tank control set to initiate charging when the hot tank level becomes sufficiently low and charges until a high level re-established
- Only HTGR electricity demand reduced to meet new operational setpoint



Results

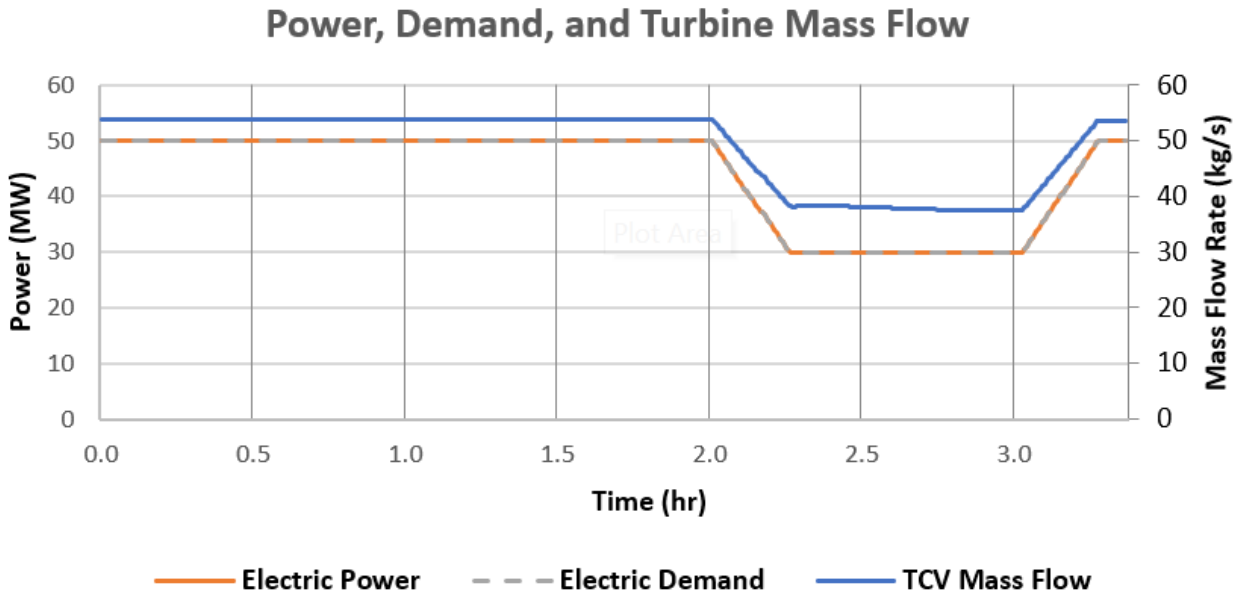
- Demand setpoints are met without large impact on reactor operations

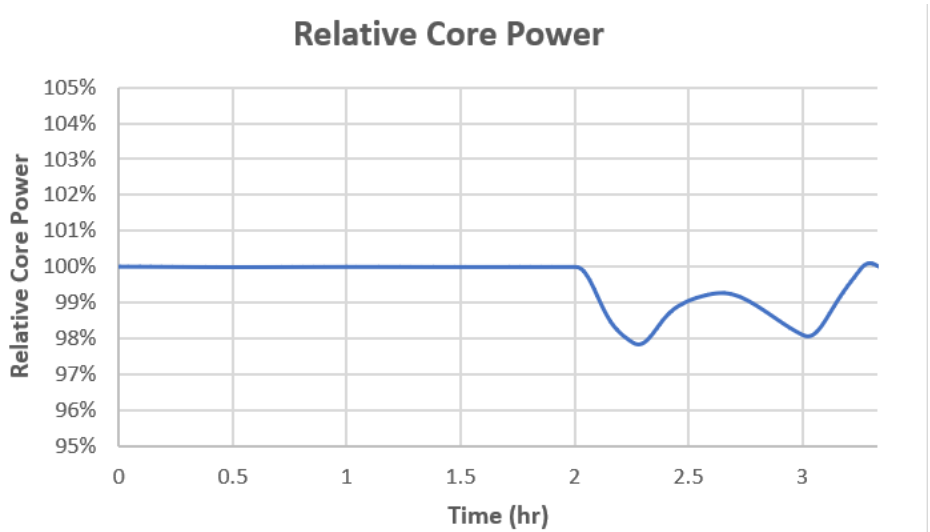




Results

- Reactor core power is maintained within ~2% of nominal power despite the imposed electrical demand change of 40%





HYBRID Results

- HYBRID contains models that can provide results for IES
- Models are modifiable to allow for IES investigations that INL has not imagined
- HYBRID is open-sourced and can be cloned from GitHub at: https://github.com/idaholab/HYBRID.git

Thank You

- Are there any questions?

- Contact:
- Daniel.Mikkelson@inl.gov

Sample Bonus Slide

- Possible to put in other HYBRID model slides here at the end, along with additional results we may want to have/show