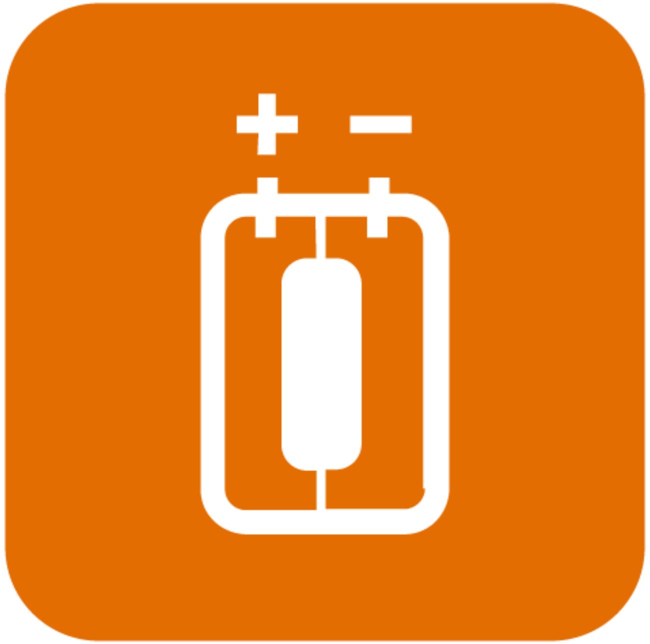
FUEL CELL LIBRARY

Overview

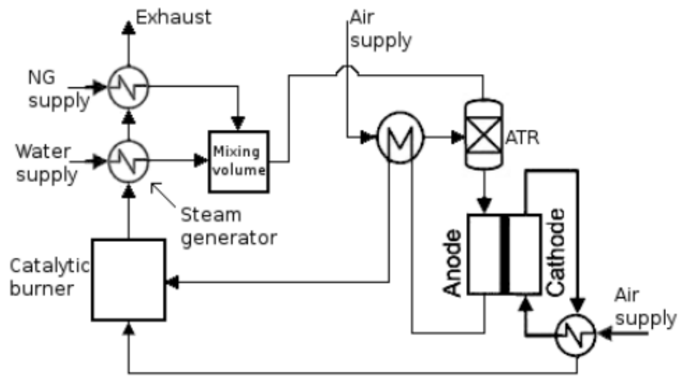
AGENDA

- About Fuel Cell Library
- Key Benefits
- Key Capabilities
- Key Applications
- Library Contents
- Modelon Compatibility
- Latest Release



ABOUT FUEL CELL LIBRARY

- Modeling and simulation of fuel cell systems for
  - Process design
    - component sizing and system integration
  - Requirement verification
  - Analysis of dynamics
  - Controller design and tuning (HIL/SIL)
  - Optimization of operating conditions to improve the system efficiency
  - Start-up sequence verification
    - avoiding costly component failures



KEY BENEFITS

- Rapid model development using pre-configurable templates and numerically efficient models & fluids
- Ready to apply out of the box, accurate and robust models with a large set of correlations
- Real time capable models for use in HIL/SIL applications
- Ability to simulate start-up sequences, standard and emergency scenarios
- Design optimization using predictive physics based model
- Extendable to various application domains:
    - Power generation
    - Automotive
    - Aerospace
    - Residential

KEY CAPABILITIES

- System and component design
- Support of Solid oxide fuel cells (SOFC) and proton exchange membrane fuel cells (PEMFC)
- Reactors for fuel pre-processing and internal stack reforming
- Reactions calculated using several approaches
  - Quasi-equilibrium, Equilibrium with reaction invariant, Reaction kinetics
- Support for various flow structures using manifolds:
  - Z-flow, U-flow, mid-flow, external
- Handles a wide range of media
  - City gas, Diesel
  - Natural gas (with and without propane and butane), reformate and other ideal gas mixture
  - Two phase condensation media
- Support for stack cooling

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KEY APPLICATIONS

CASE STUDY

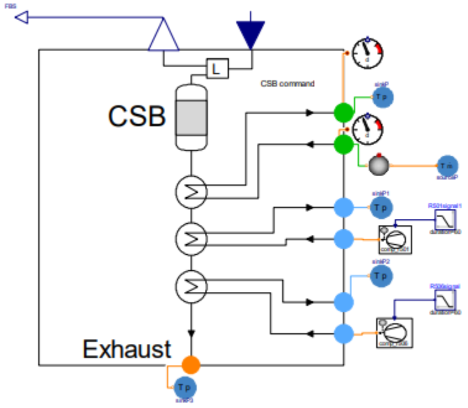
HIL Testing of a Truck Auxiliary Power Unit (APU)

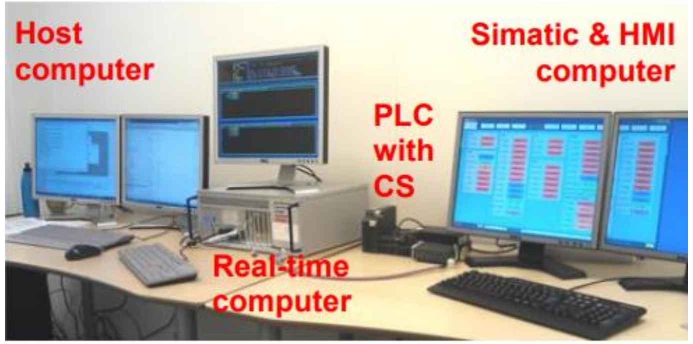
Objective

Verify failsafe and environmentally friendly PLC start-up sequence in an APU to avoid costly component failures during testing.

Results

- Verified PLC implementation
- Cost and time savings by minimizing component failures during prototype testing.





In collaboration with:

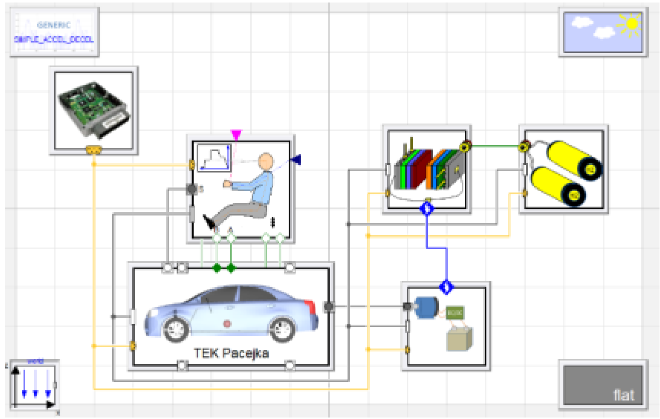
CASE STUDY

Fuel Cell Vehicle Drive Cycle Simulation

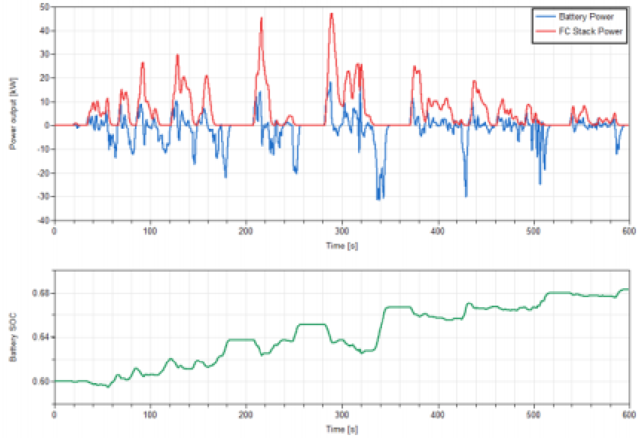
Objective

Evaluate the performance of a fuel cell vehicle during a full drive cycle simulation, monitoring the overall performance and efficiency and predicting the behavior of a real vehicle.

Results



- A flexible model architecture for hybrid hydrogen fuel cell vehicles, covering physical phenomena across thermal, fluid, electrical and mechanical
- Real-time capable for HIL/SIL testing



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CASE STUDY

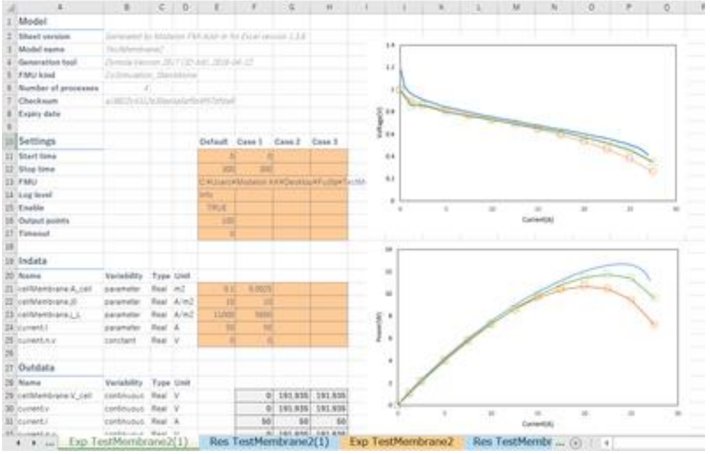
Polymer Electrolyte Membrane Fuel Cell Validation

Objective

Researchers at Tokyo Metropolitan University set out to create a PEMFC test bench model for virtual design optimization.

Results

- Validated PEMFC model ready to be used for design optimization and control scheme development.



Parameter setup with using FMI

In collaboration with:

TOKYO METROPOLITAN UNIVERSITY

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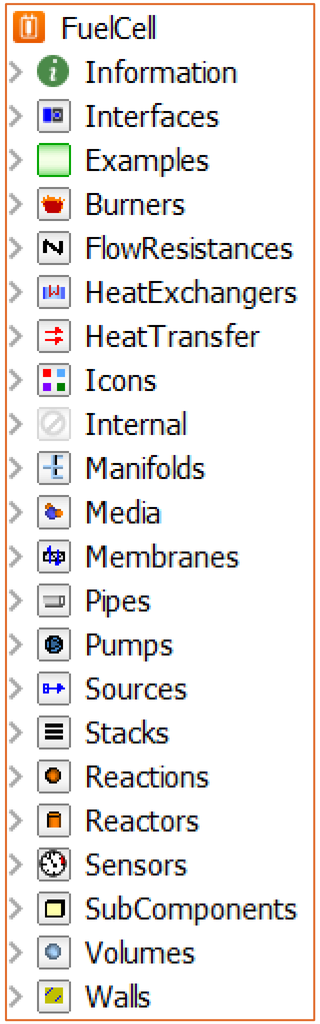
LIBRARY CONTENTS

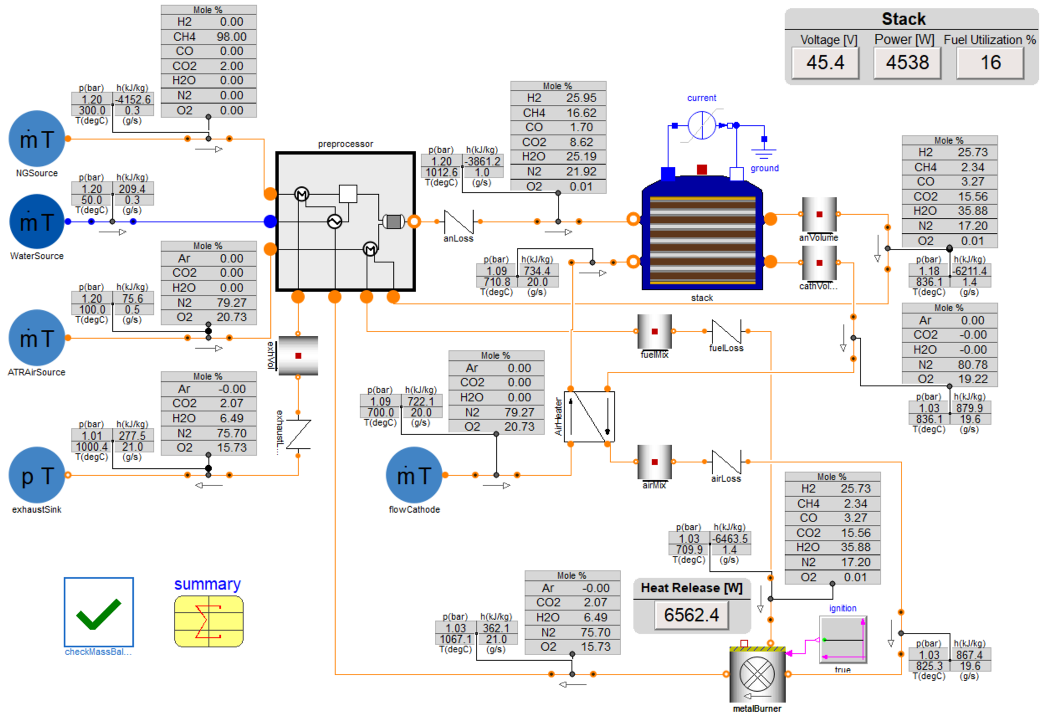
LIBRARY CONTENTS

- Examples displaying typical use-cases and capabilities
- Fuel cell components
  - Reaction models
  - Membranes
  - Stacks
- Auxiliary system components
  - Heat exchangers
  - Pumps
  - Pipes
- Media models



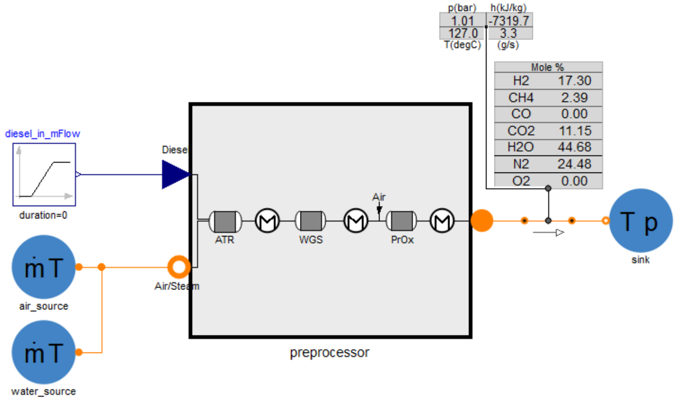
LIBRARY CONTENTS

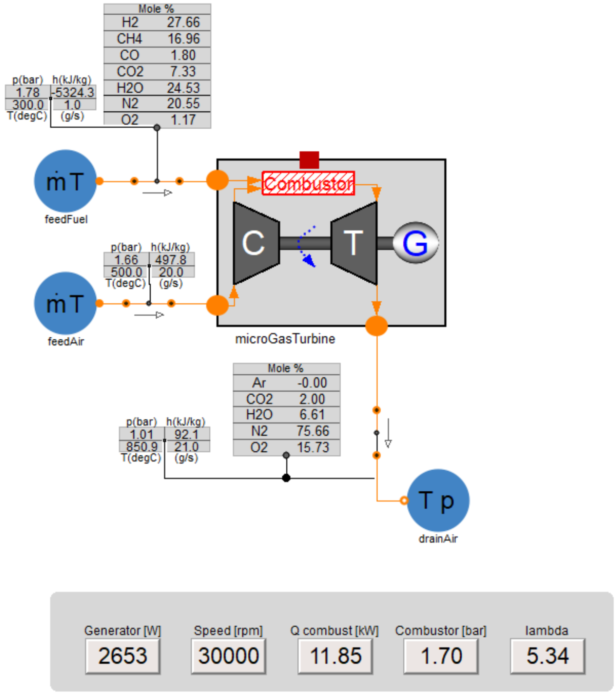
- 5 kW Solid Oxide Fuel System example
    - Addresses complex thermal interactions
  - Fed with natural gas, air and water
  - Pre-reforming of natural gas
  - Stack with 60 cells, manifolds and insulation
  - Catalytic afterburner to
    - Burn remaining fuel
    - Pre-heat the fuel and generate steam in the preprocessor

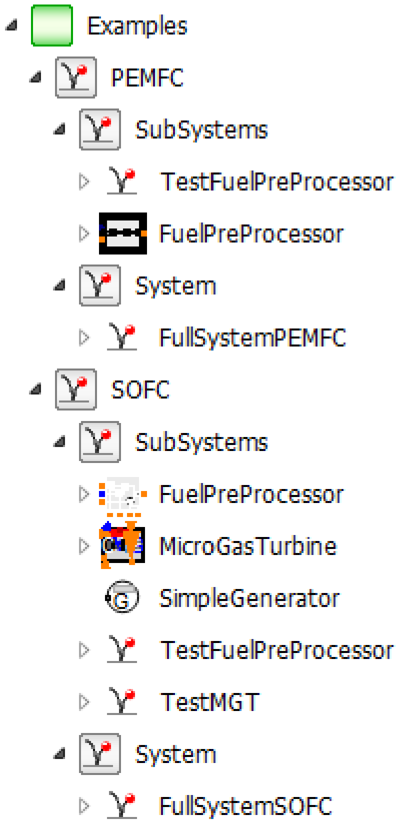


LIBRARY CONTENTS

- Preprocessor and Micro gas turbine examples

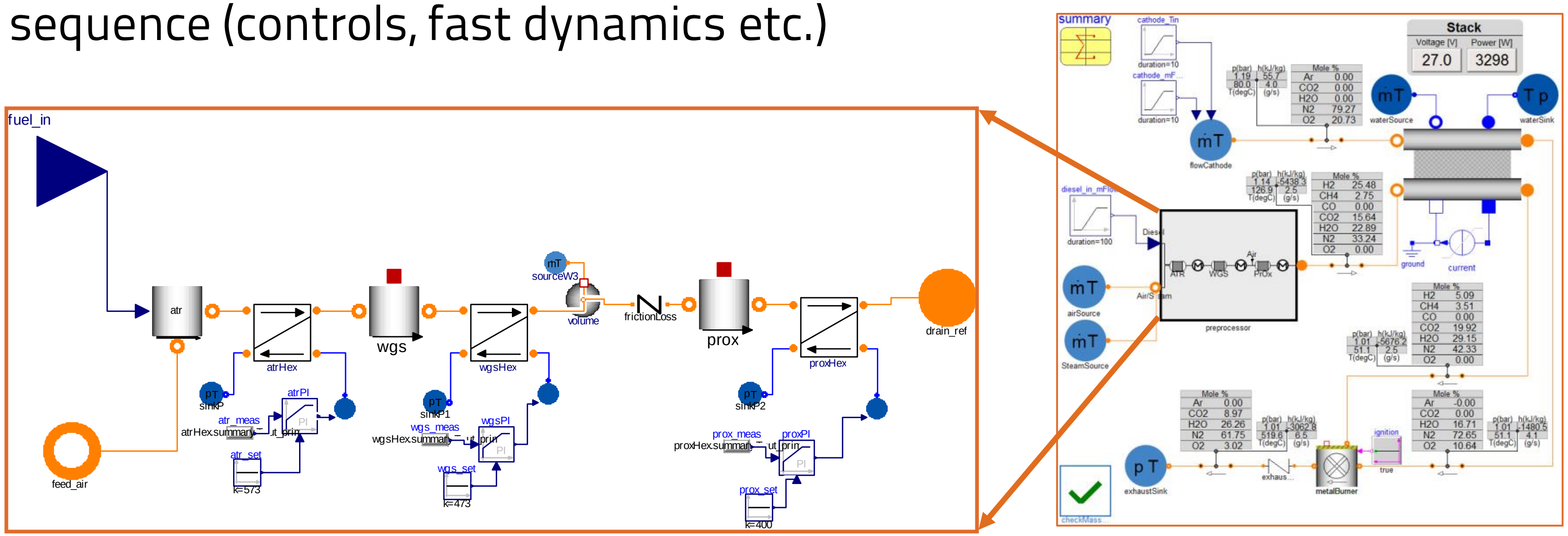






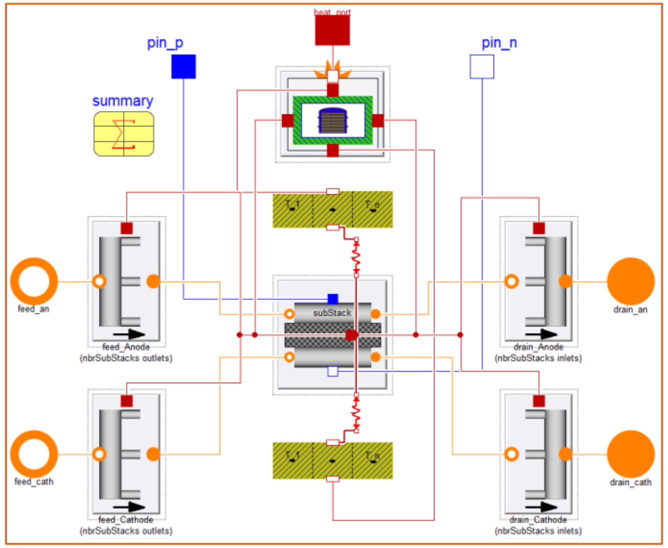
LIBRARY CONTENTS

- Diesel Fueled auxiliary power unit (APU) for trucks
  - Fed with hydrogen-rich gas made from reformed diesel
- Challenges:
  - CO content in pre-reformed gas must be < 25 ppm.
  - Fast dynamics in pre-processing unit due to chemical reactions
  - Start-up sequence (controls, fast dynamics etc.)

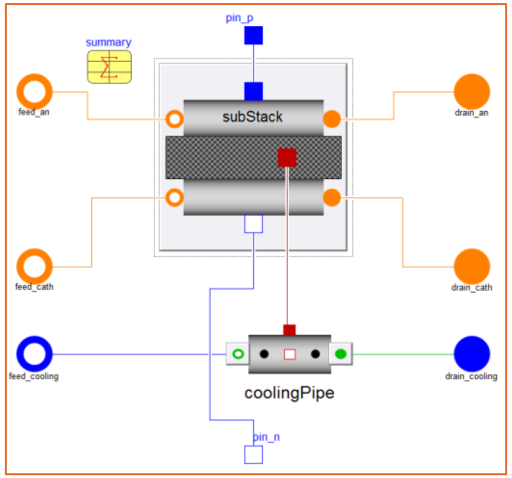


LIBRARY CONTENTS

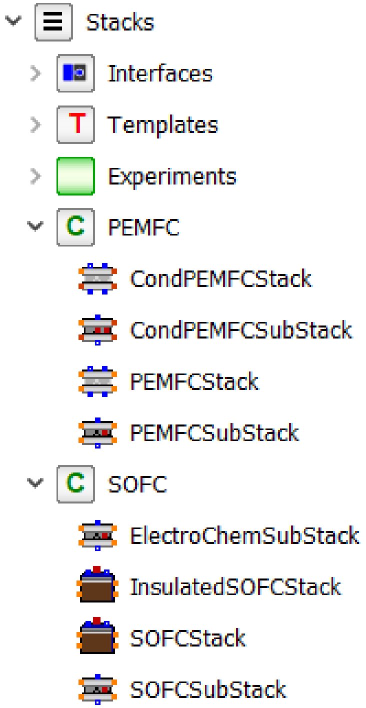
- Stack and templates
  - Substacks connected thermally in parallel
- Templates for full stack configurations
  - With or without cooling
- Support for various manifold configurations



An example of SOFC stack



An example of water-cooled stack



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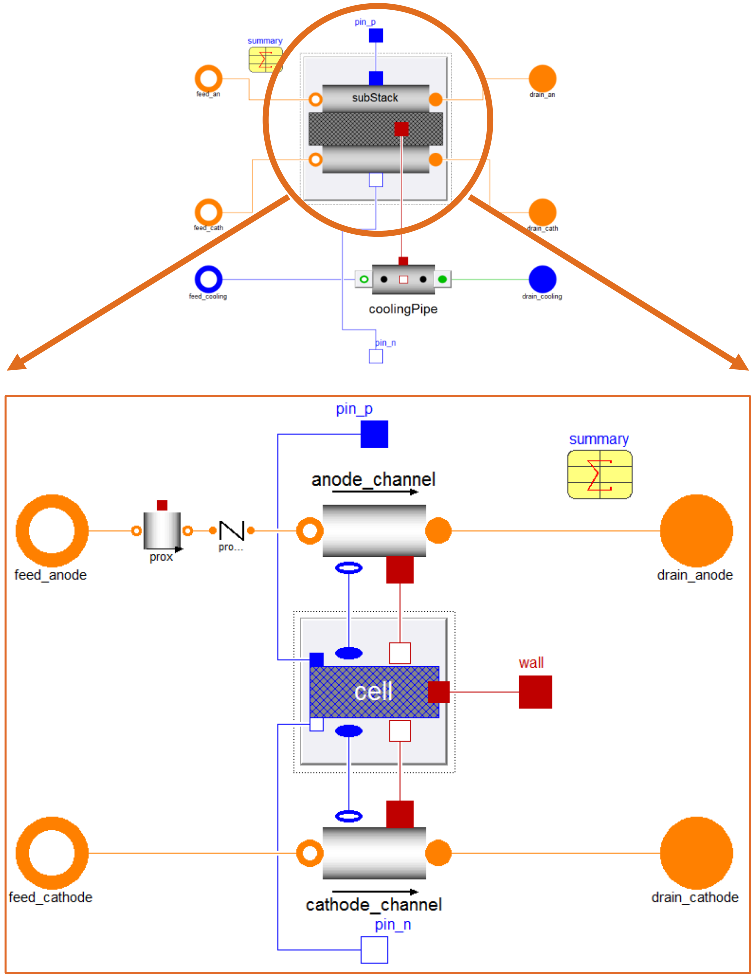
LIBRARY CONTENTS

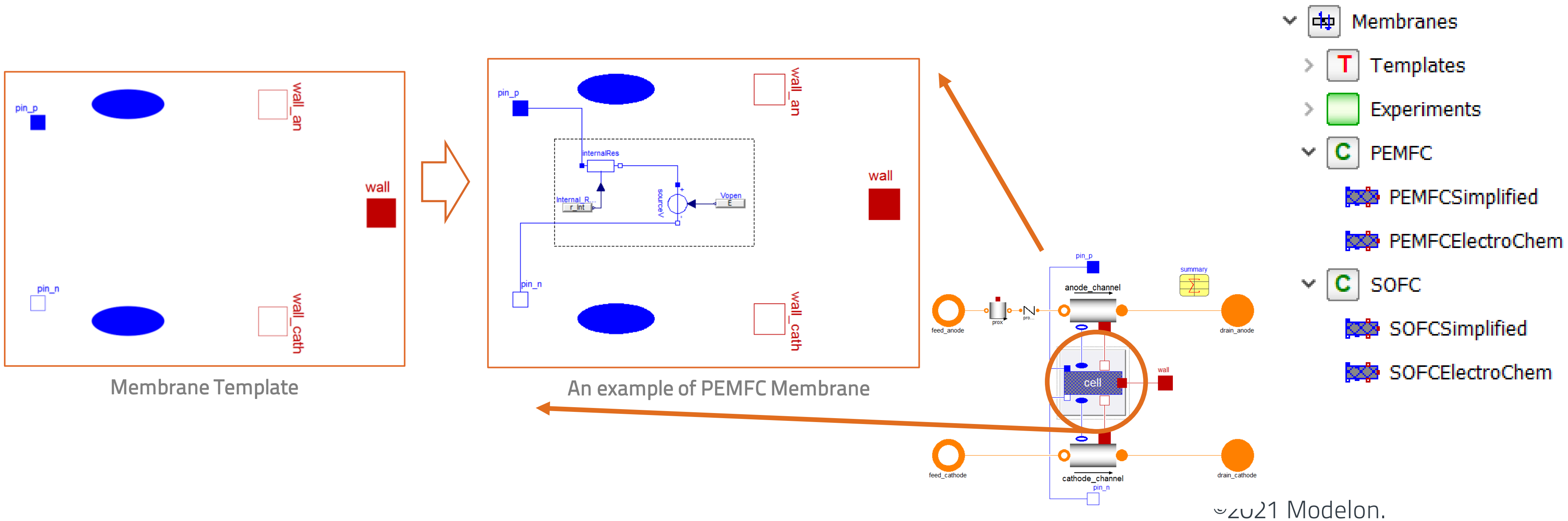
- Substacks
  - Anode and cathode channels connected to a membrane model
  - 1D discretization along flow direction
  - Flexible fidelity level option
    - Multiple cells or single for faster simulations
  - Support for condensation in the flow channels



An example of PEMFC substack

LIBRARY CONTENTS

- Membranes
    - Detailed electrochemical models or simplified models for real-time applications
    - Define the electrical behavior of the fuel cell (including different kinds of losses) and the fuel cell reaction: $2H_2 + O_2 \rightarrow 2H_2O$

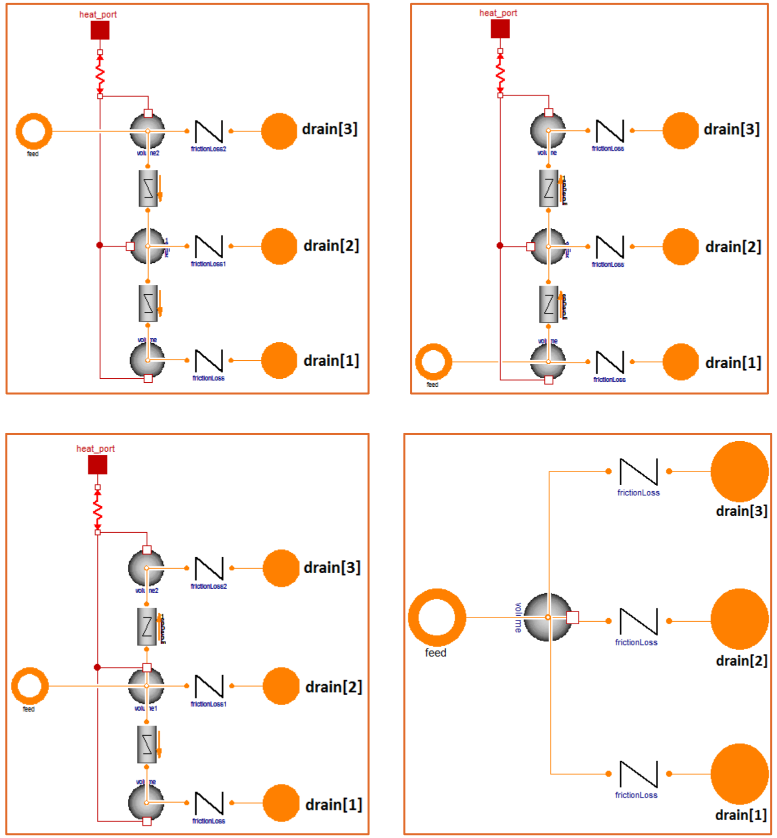


Membrane Template

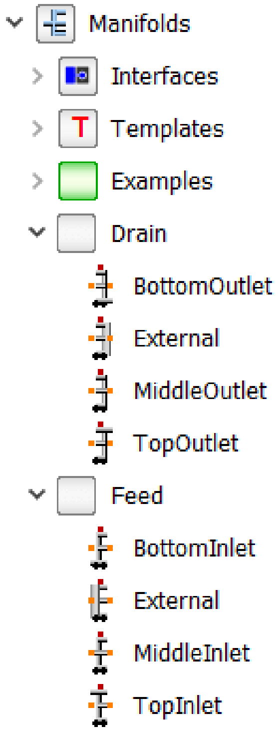
An example of PEMFC Membrane

LIBRARY CONTENTS

- Manifolds for different flow configurations
  - Internal manifolds
  - External manifolds
- Can be used to achieve
  - U-flow
  - Z-flow
  - Mid-flow
  - Equally distributed flows

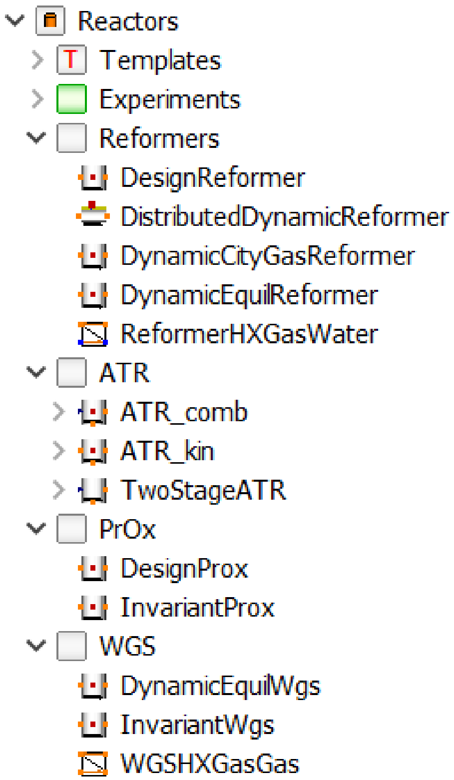


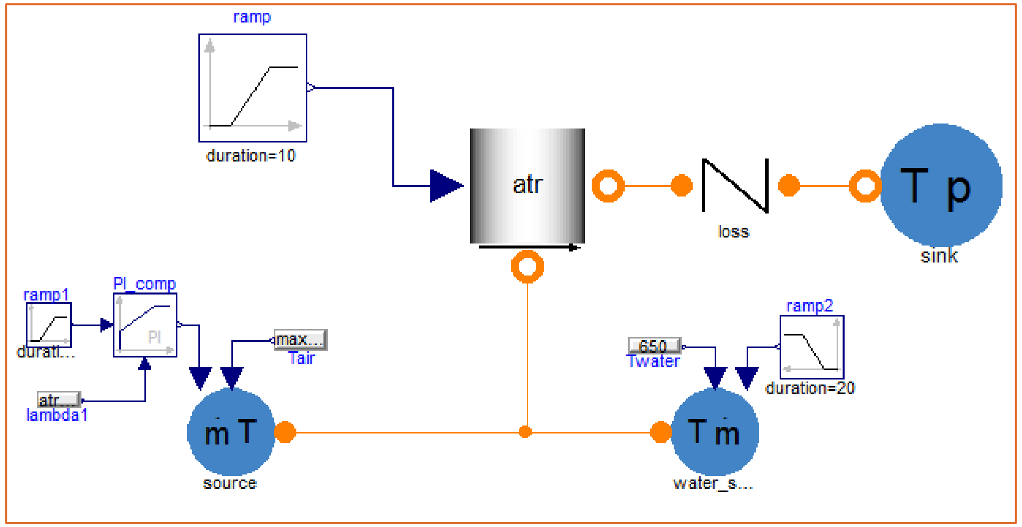
Different types of manifolds



LIBRARY CONTENTS

- Reactors
  - Lumped reactors
  - Discretized pipe reactors
    - Internal reforming (SOFC)
    - Plate HEX reactor coated with catalyst





Test model for a auto thermal reformer

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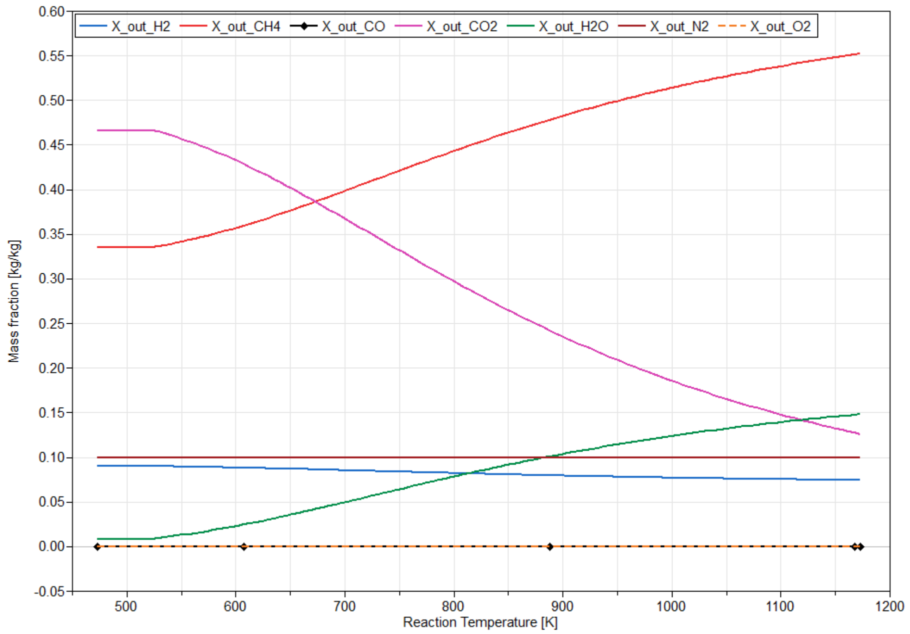
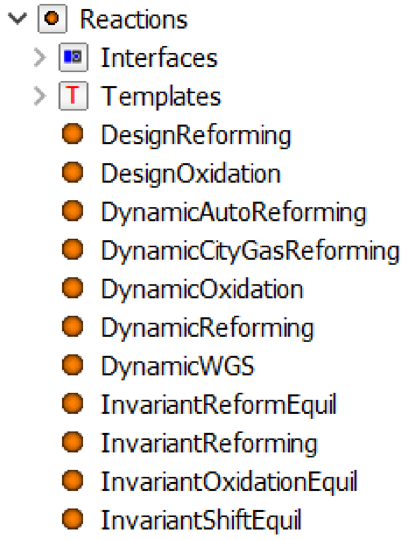
LIBRARY CONTENTS

- Reactions
  - Reactions modelled in three approaches:
    - Equilibrium with reaction invariants
    - Quasi-equilibrium reactions
    - Reaction kinetics

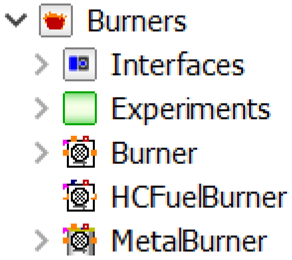


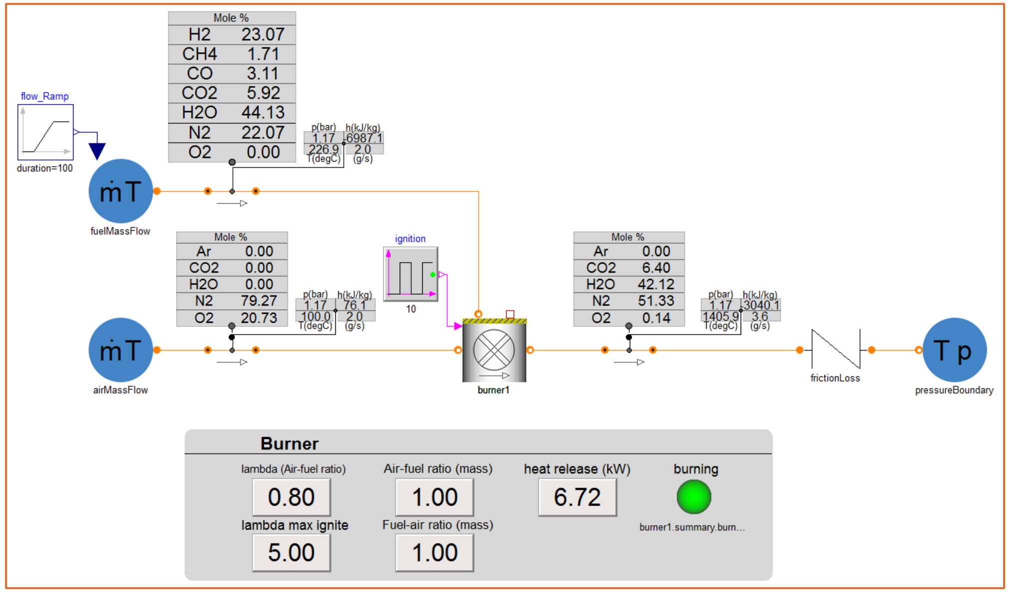
Equilibrium mass fractions for methane reforming at different temperatures



LIBRARY CONTENTS

- Burners
  - Start-up burners
  - Catalytic afterburners
  - Purpose
    - Pre-heating
    - Burning excess fuel
    - Steam generation
  - Combustion efficiency as the main parameter

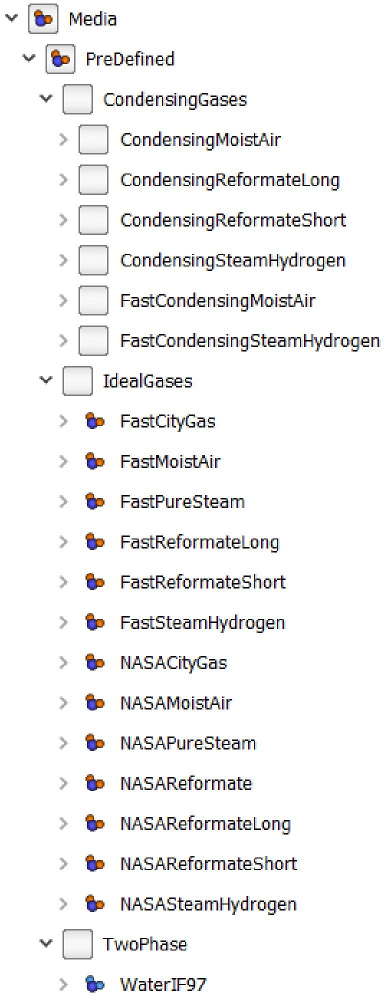




Test model for a burner

LIBRARY CONTENTS

- Media properties
  - Reaction media
    - Ideal gas using NASA polynomials
    - Used in reactors
    - Common reaction properties
    - Suitable when the temperature, T, and the amount of substance, Z, are used as states
  - Condensing media
    - Ideal gas with simplified liquid water model
  - Two Phase media
    - Support for the industry standard IAPWS-IF97
  - Fast media for real-time applications
    - Low order polynomials with analytic inverses



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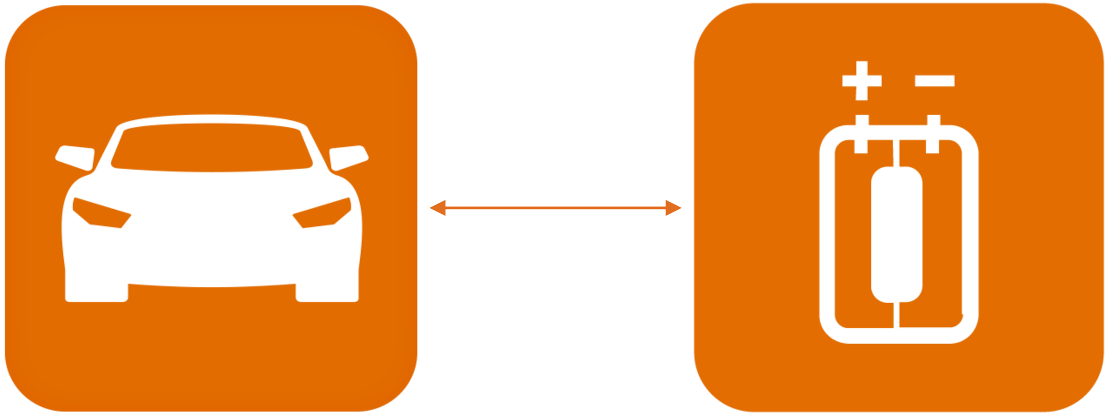
MODELON COMPATIBILITY

RECOMMENDED MODELON LIBRARY COMPATIBILITY

- Modelon's Fuel Cell Library is compatible with Modelon's Vehicle Dynamics Library for the creation of fuel cell vehicle models.



LATEST RELEASE

RELEASE: 2021.2

Enhancements

- Improvements in CondPEMFCStack and CondPEMFCSubStack in which the components did not scale automatically with number of cells
- Energy balance calculation and summary variables of EpsNTUHumidifier improved
- The membrane model in PEMFCSubStack has been made replaceable

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