Working groups on “modelling of NHES”

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How to study NHES?

Techno-economic assessment of NHES

. Technical feasibility
- . New process system to be studied (e.g., performance)
- . **Dynamic exchange of interconnected energy streams (steam, electricity, hydrogen, …)**
- . Monitoring of process and data for real-time decision (control)

. Economic feasibility
- . Impact of new structure of costs (capital and operational)
- . Assessment of plant revenues in new market (heat and H2)
- . Optimization of cost at system-level

+ Unit sizing, dispatch optimization, resource assessment, infrastructure requirements, development of new policies

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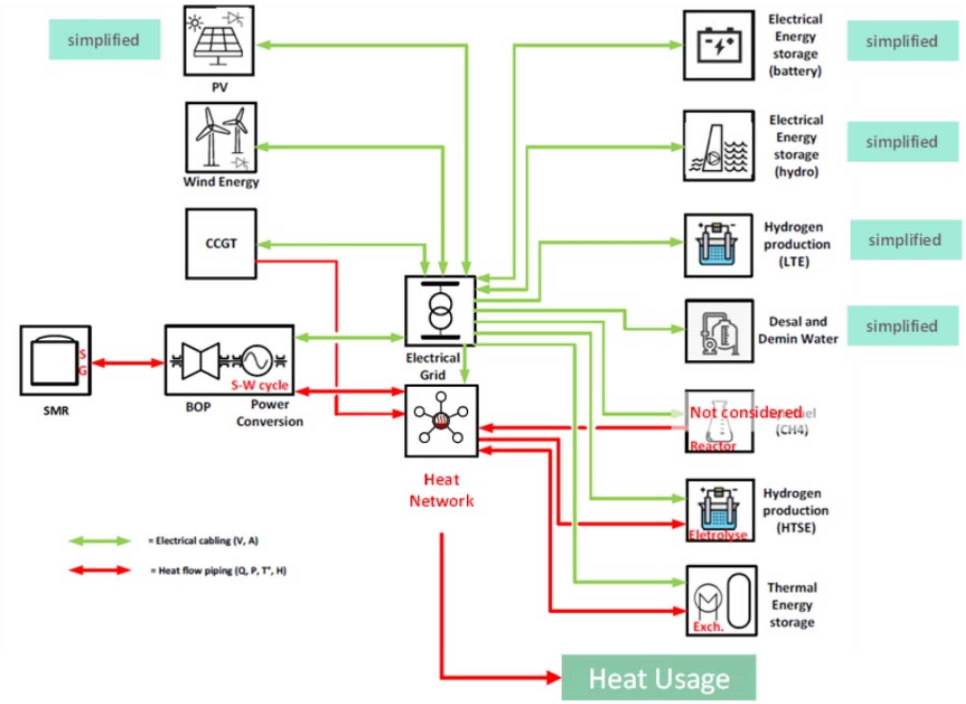
How to study NHES?



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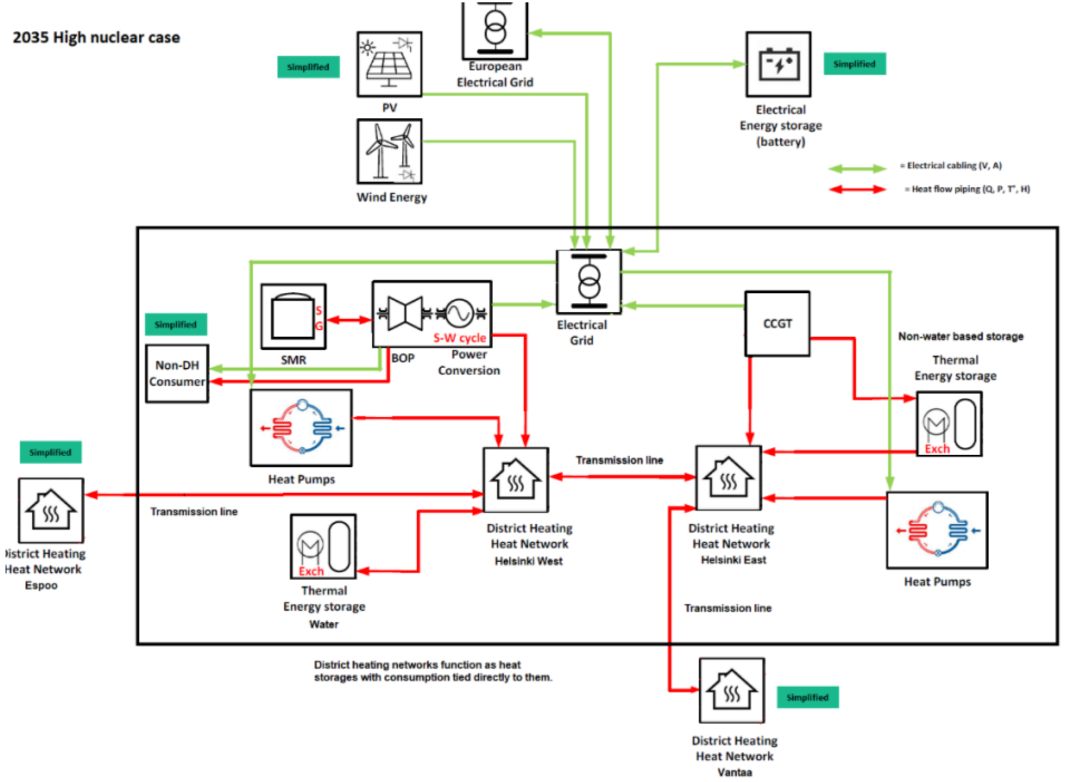
How to study NHES?



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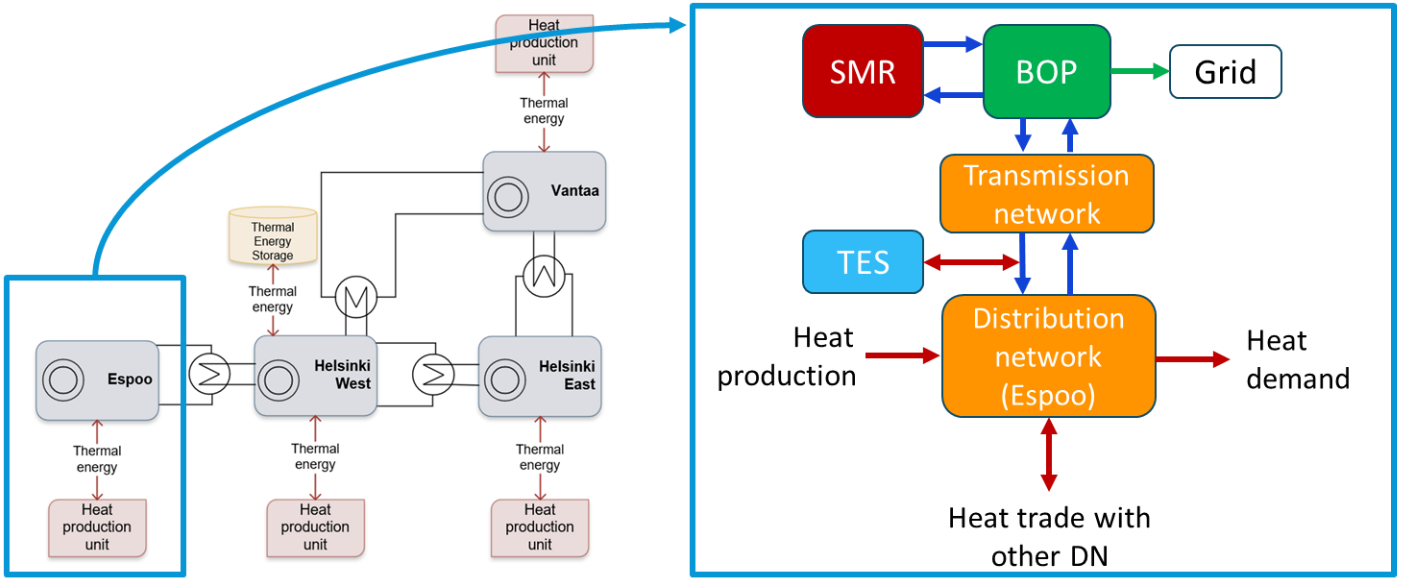

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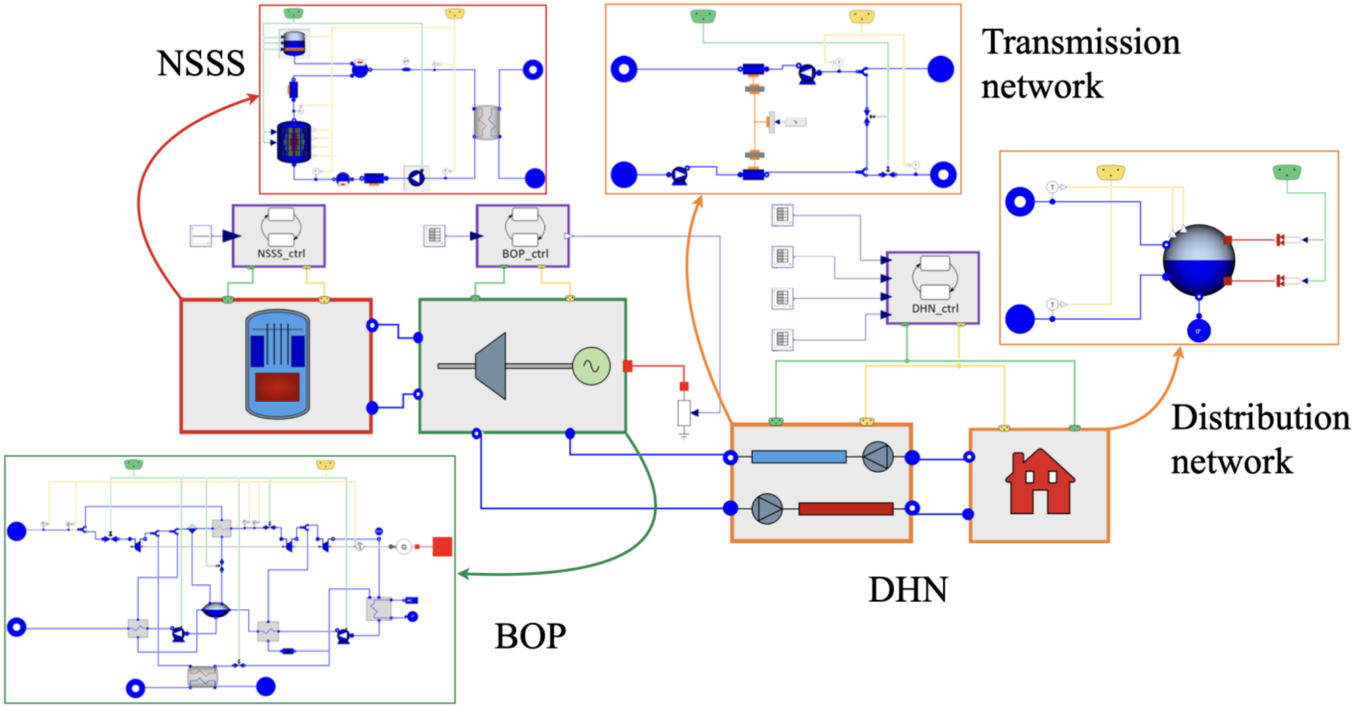

Introduction to Modelica

Modelling options

- Data-driven, needs input-output info
- Model-based, requires physics knowledge

Equation-based Object-Oriented modelling is the natural choice for the model-based simulation

Modelica is a modelling language

https://modelica.org/

MODELICA

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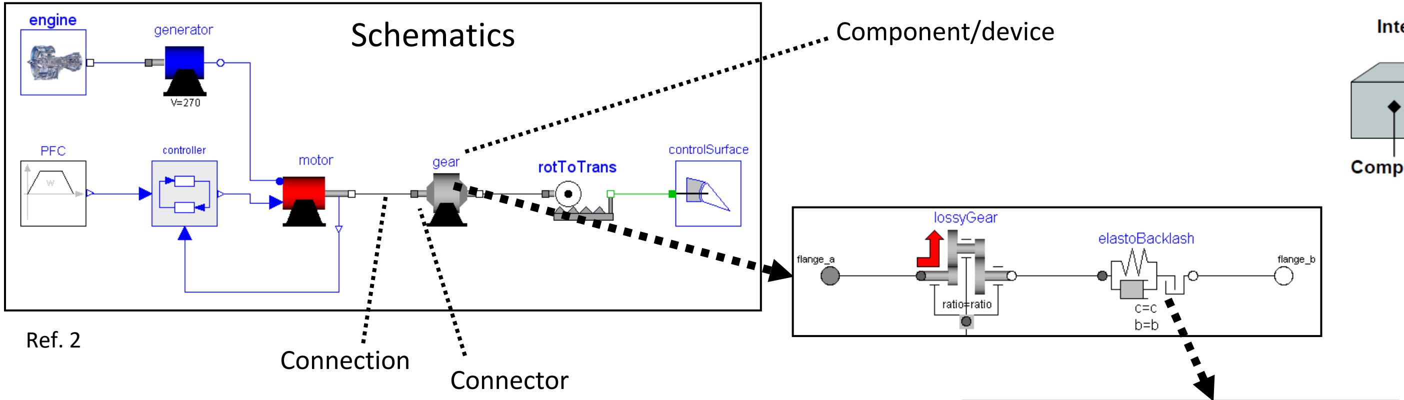
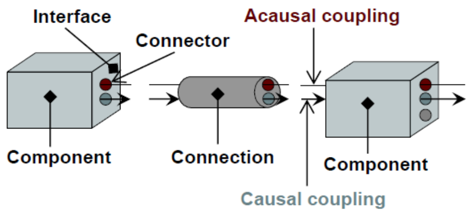
Introduction to Modelica



Ref. 2

```
equation
        0 = flange_a.tau + flange_b.tau;
  phi_rel = flange_b.phi - flange_a.phi;
    w_rel = der(phi_rel);
      ...
```



Ref. 3

. Each Icon represents a physical component (electrical resistance, pipe, turbine, ...)

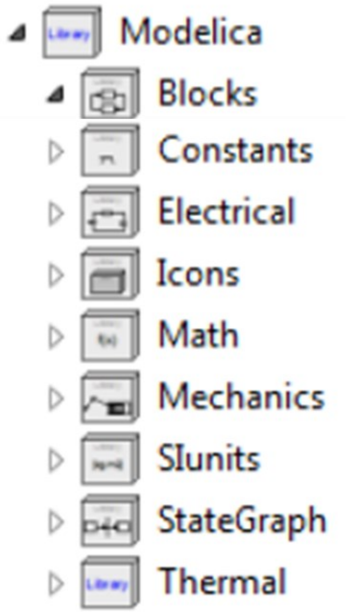
. A connection line represents the actual physical coupling (wire, fluid flow, heat flow, ...)

. Variable at the interface describe interaction with other components

. A component consists of connected sub-components and is described by equations

Introduction to Modelica

Modelica Standard Library



Ref. 3

- **Blocks** Library for basic input/output control blocks
- **Constants** Mathematical constants nature
- **Electrical** Library for electrical models
- **Icons** Icon definitions
- **Fluid** 1-dim Flow in networks of vessels, pipes, …
- **Math** Mathematical functions
- **Magnetic** Magnetic – for magnetic applications
- **Mechanics** Library for mechanical systems
- **Media** Media models for liquids and gases
- **SIunits** Type definitions based on SI units
- **Stategraph** Hierarchical state machines
- **Thermal** Components for thermal systems
- **Utilities** Utility functions especially for scripting

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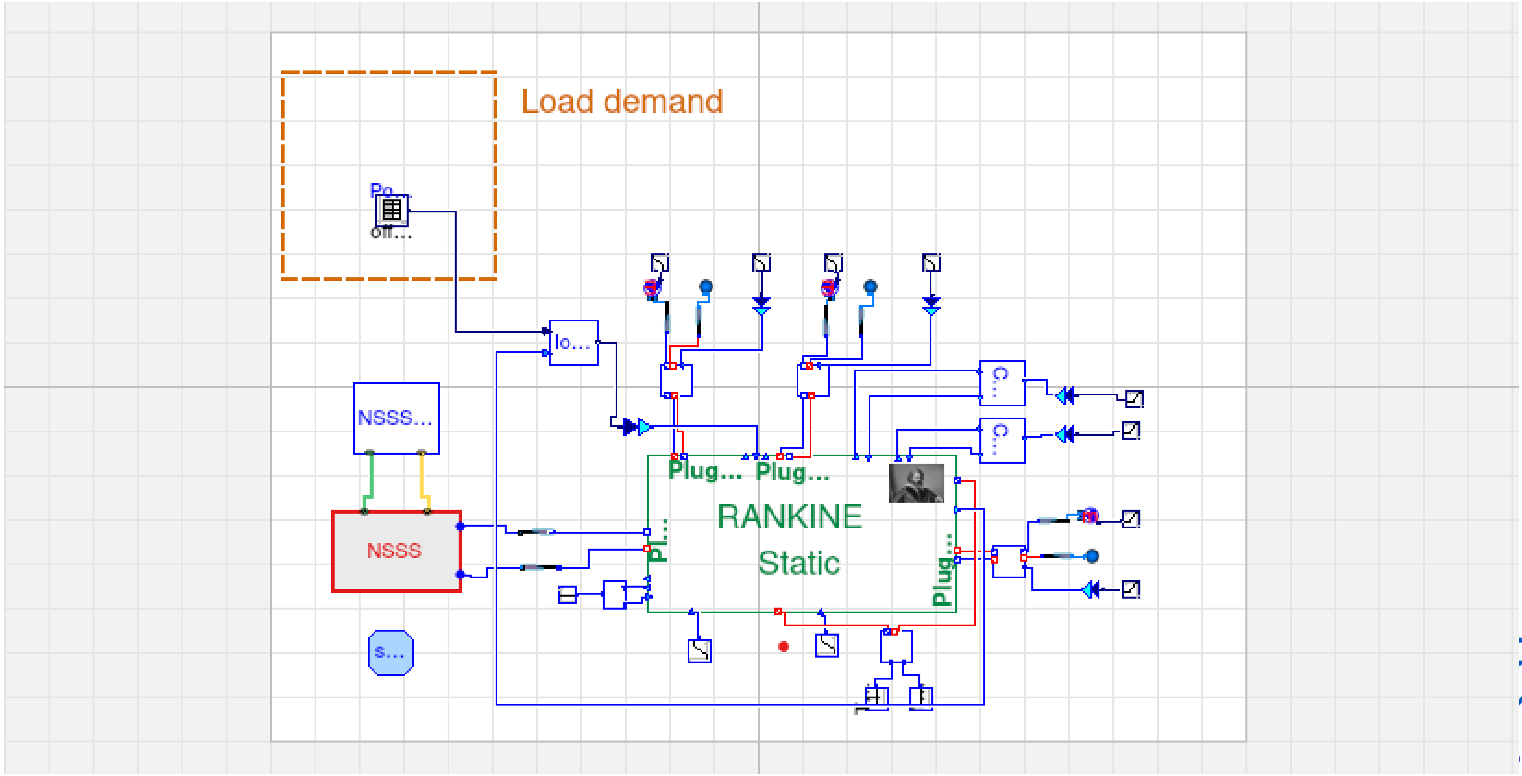
Working groups

Assigment 1 – Load following capability



Assigment 1 – Load following capability

- Simulate the reactors at constant power and check the main variables in NSSS (thermal power, temperatures, mass flow rates,…) and BoP (electrical power, temperatures, pressures, mass flow rates,…)

- Modify the power profile, e.g., with a 10% ramp down
    - check how the reactor is controlled
    - check how (and if) the main variables have changed

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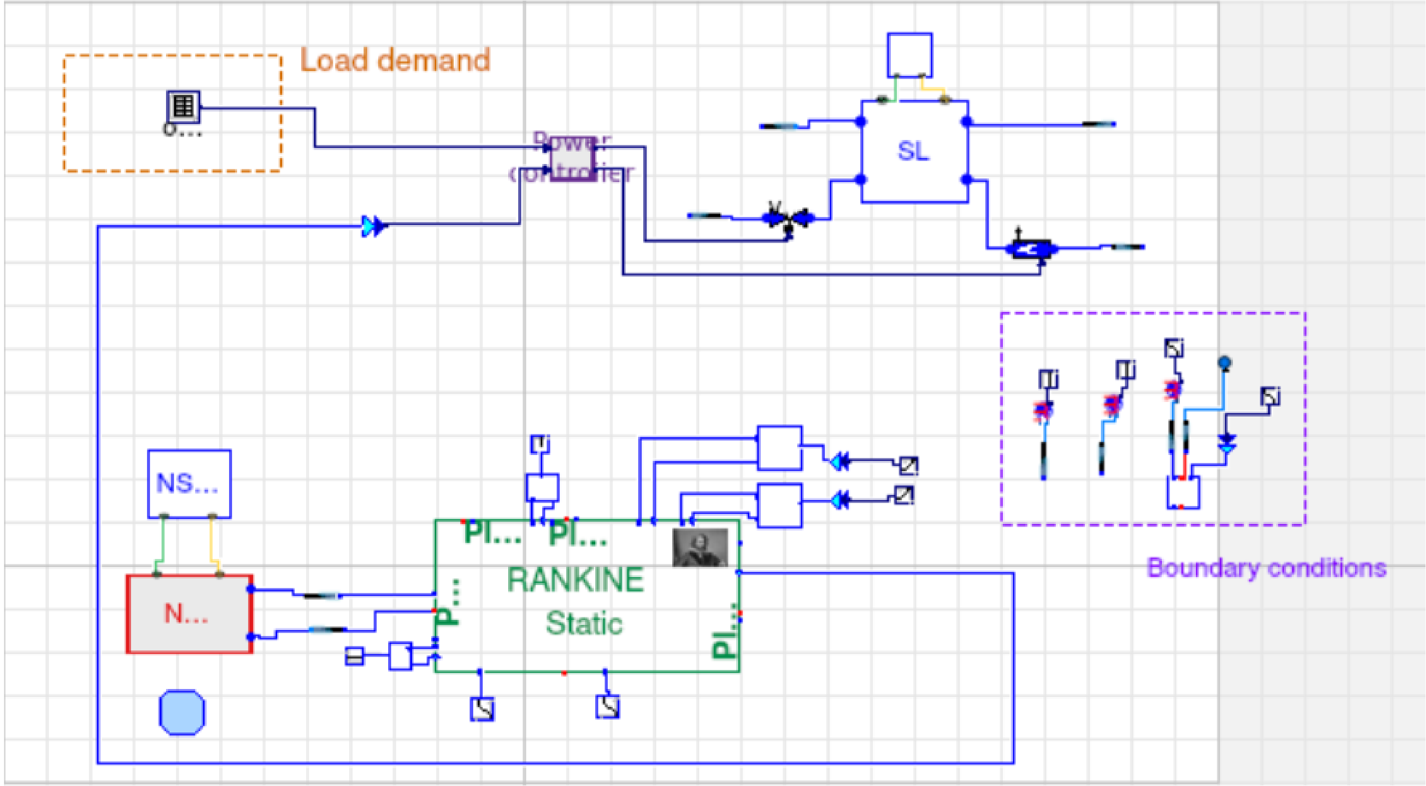
- Modify the power profile, e.g., with a 10% ramp down
    - check how the reactor is controlled
    - check how (and if) the main variables have changed

- Consider to perform load following to avoid RES (solar) curtailment. Make hypothesis about the solar daily power curve and adjust the power of the reactor accordingly
    - check how the reactor is controlled
    - check how (and if) the main variables have changed

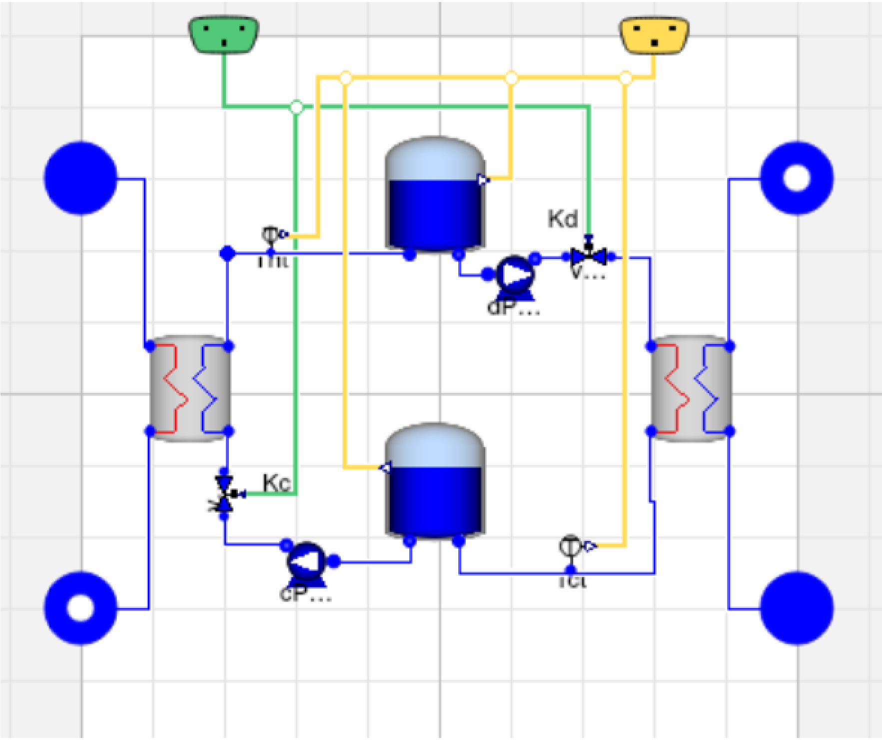
Assigment 2 – Thermal storage



Assigment 2 – Thermal storage

Inlet charging

Outlet charging

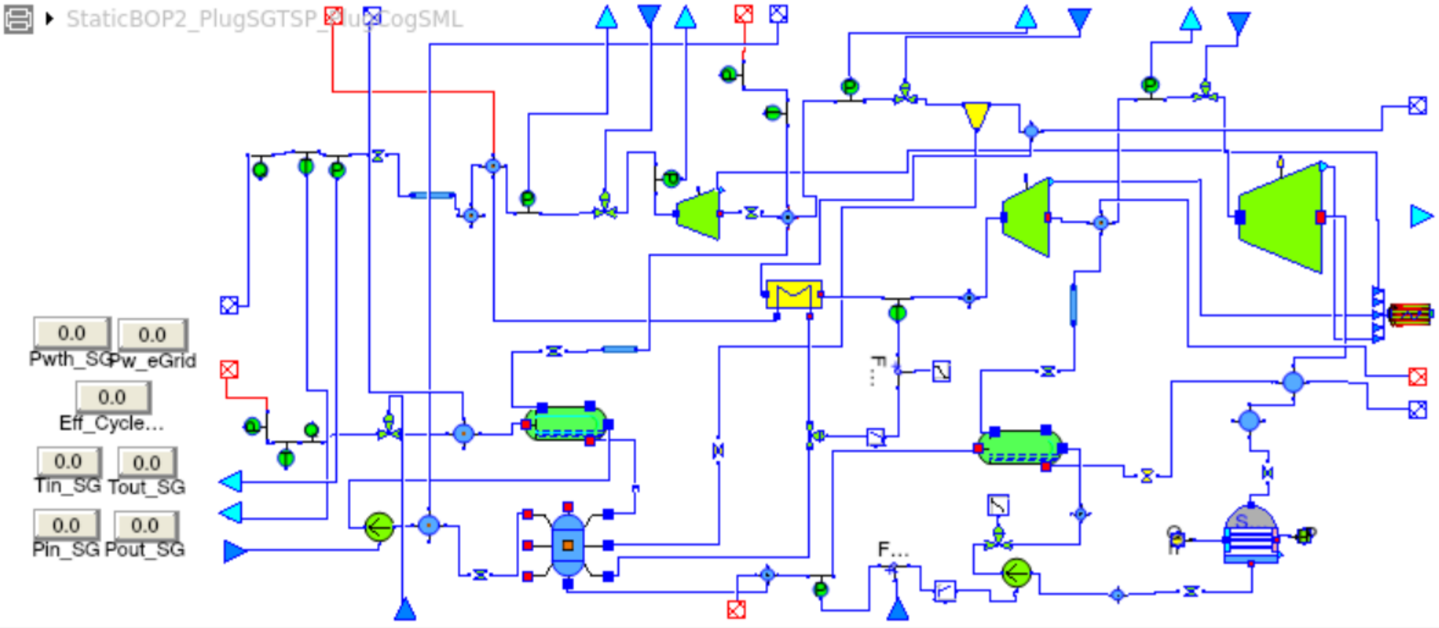


Outlet discharging

Inlet discharging

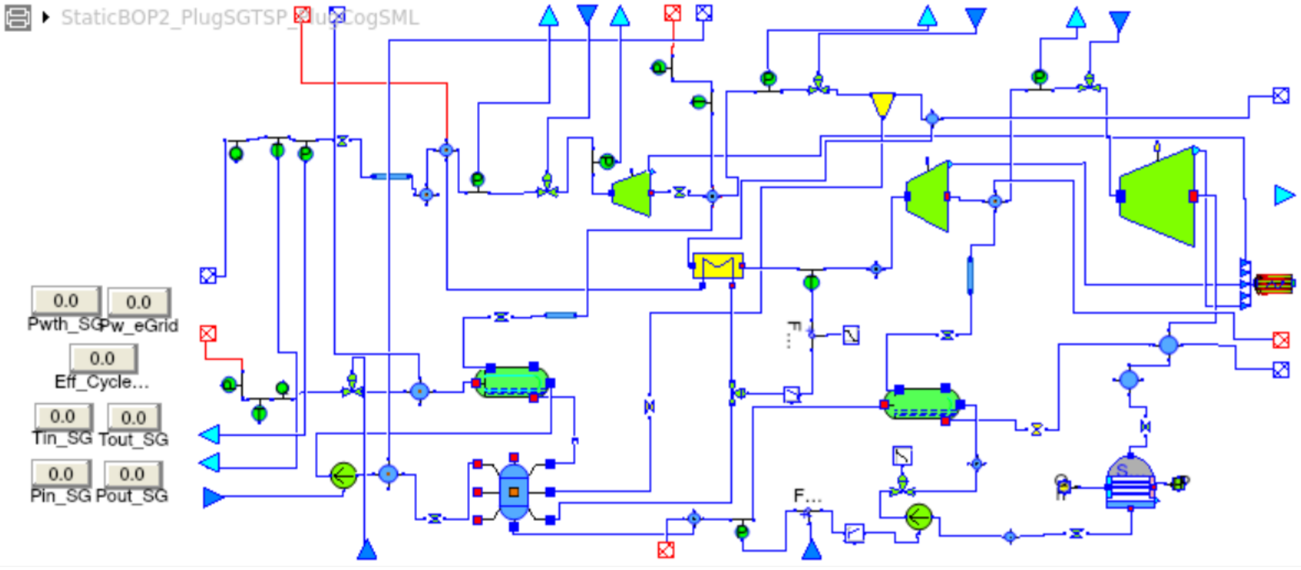
Assigment 2 – Thermal storage

- Identify which is the most suitable connection for the thermal storage system for your NHES. Connect the thermal storage and use the BC to "close" the system



Assigment 2 – Thermal storage

- Hint 1: for charging the TES, you want to use high temperature steam (before the HP turbine) and re-inject before the preheater after the deaerator.



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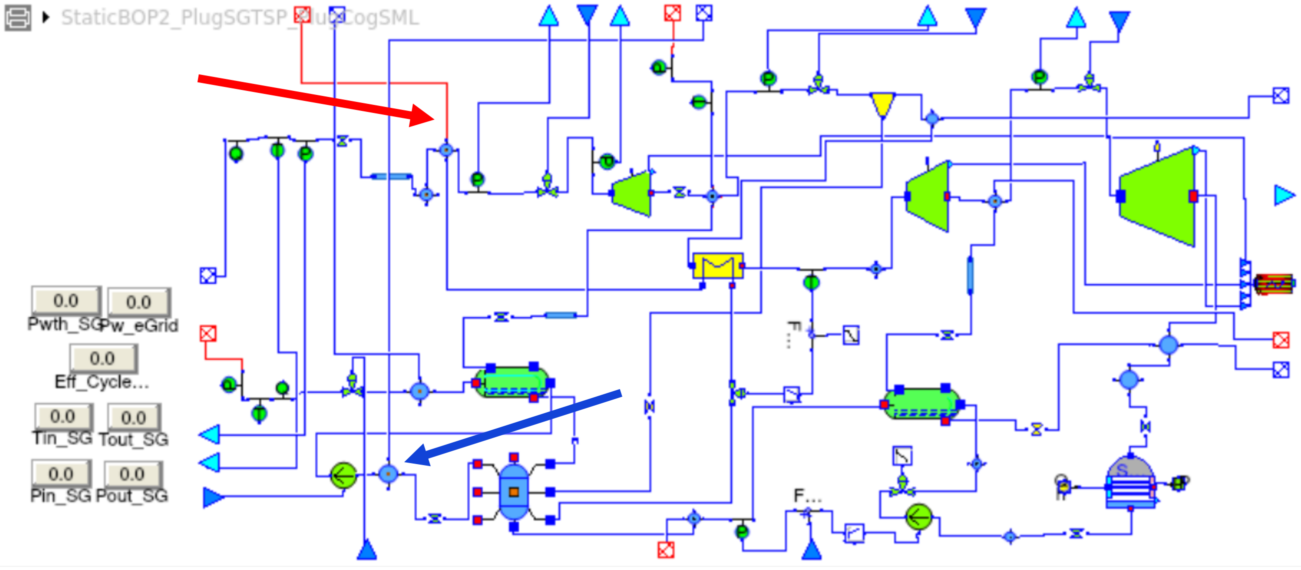
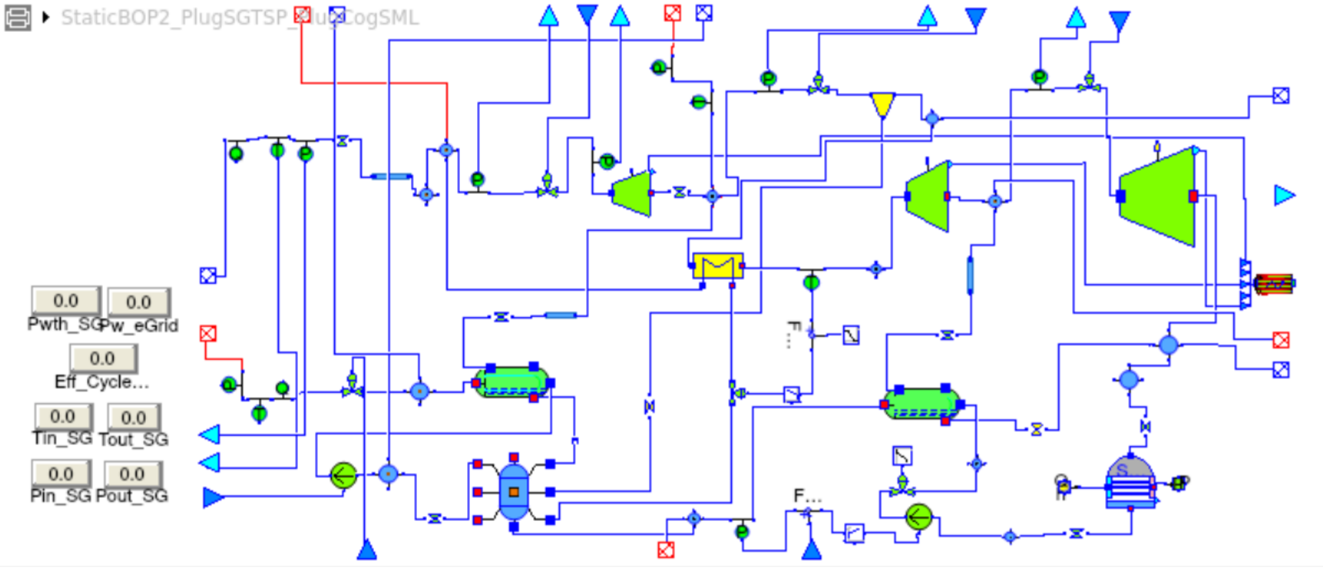


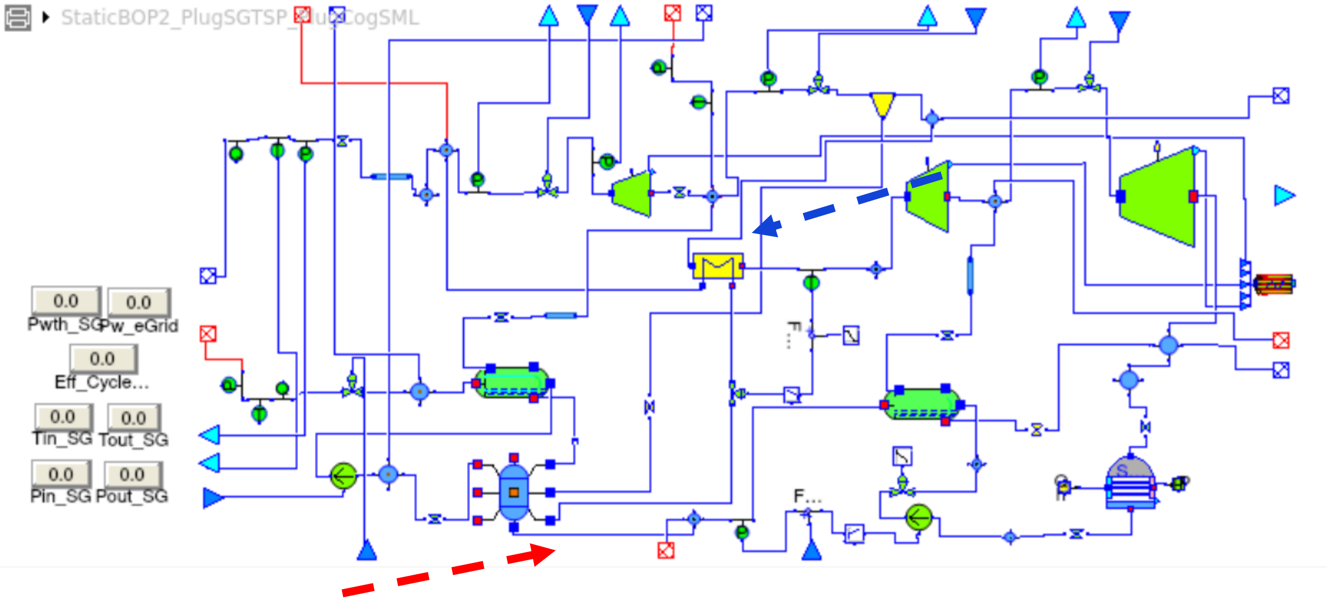
Assigment 2 – Thermal storage

- Hint 2: for discharging the TES, you want to use process water (just before the deaerator) and re-inject before the LP turbine



Assigment 2 – Thermal storage

- Hint 2: for discharging the TES, you want to use process water (just before the deaerator) and re-inject before the IP turbine



Assigment 2 – Thermal storage

- Identify which is the most suitable connection for the thermal storage system for your NHES. Connect the thermal storage and use the BC to “close” the system.
- Run your NHES and see the status of charge of the thermal energy storage

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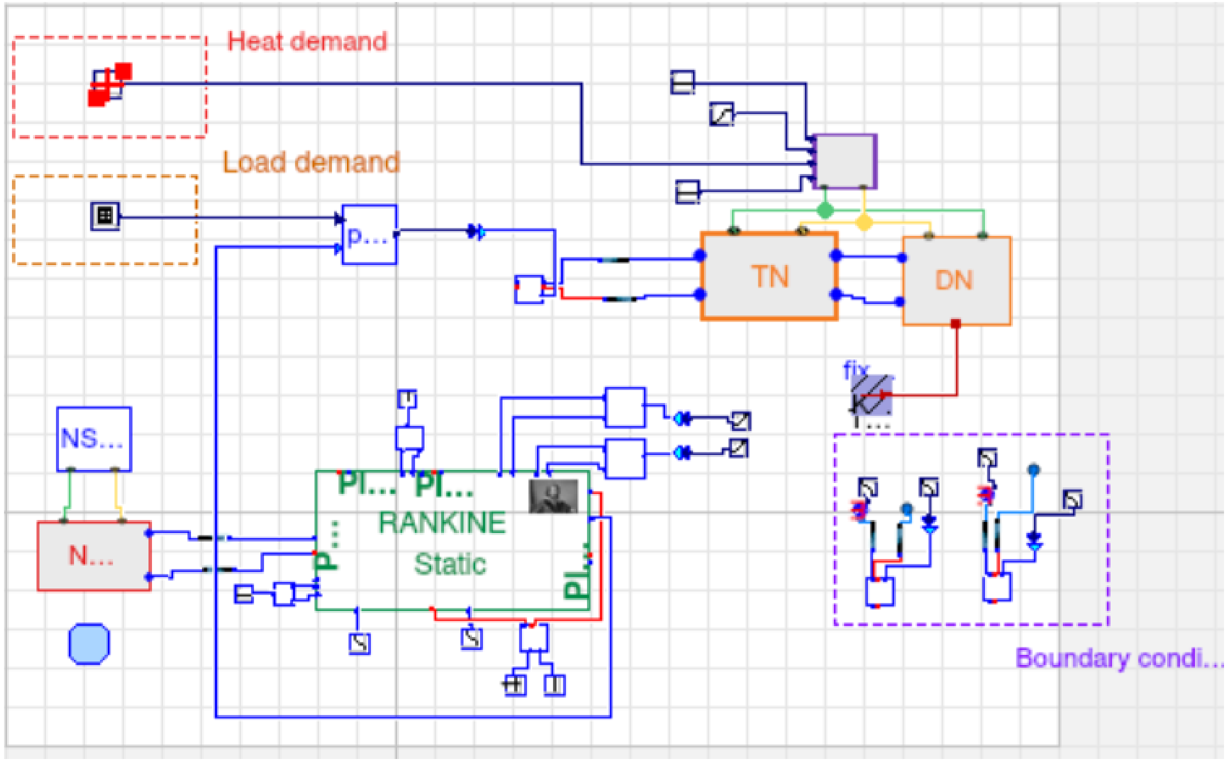
- Identify which is the most suitable connection for the thermal storage system for your NHES. Connect the thermal storage and use the BC to “close” the system.
- Run your NHES and see the status of charge of the thermal energy storage
- Run your NHES with the load demand of yesterday (profile considering the RES contribution) and see the status of charge of the TES. What happened? Comment the results

Assigment 3 – District heating



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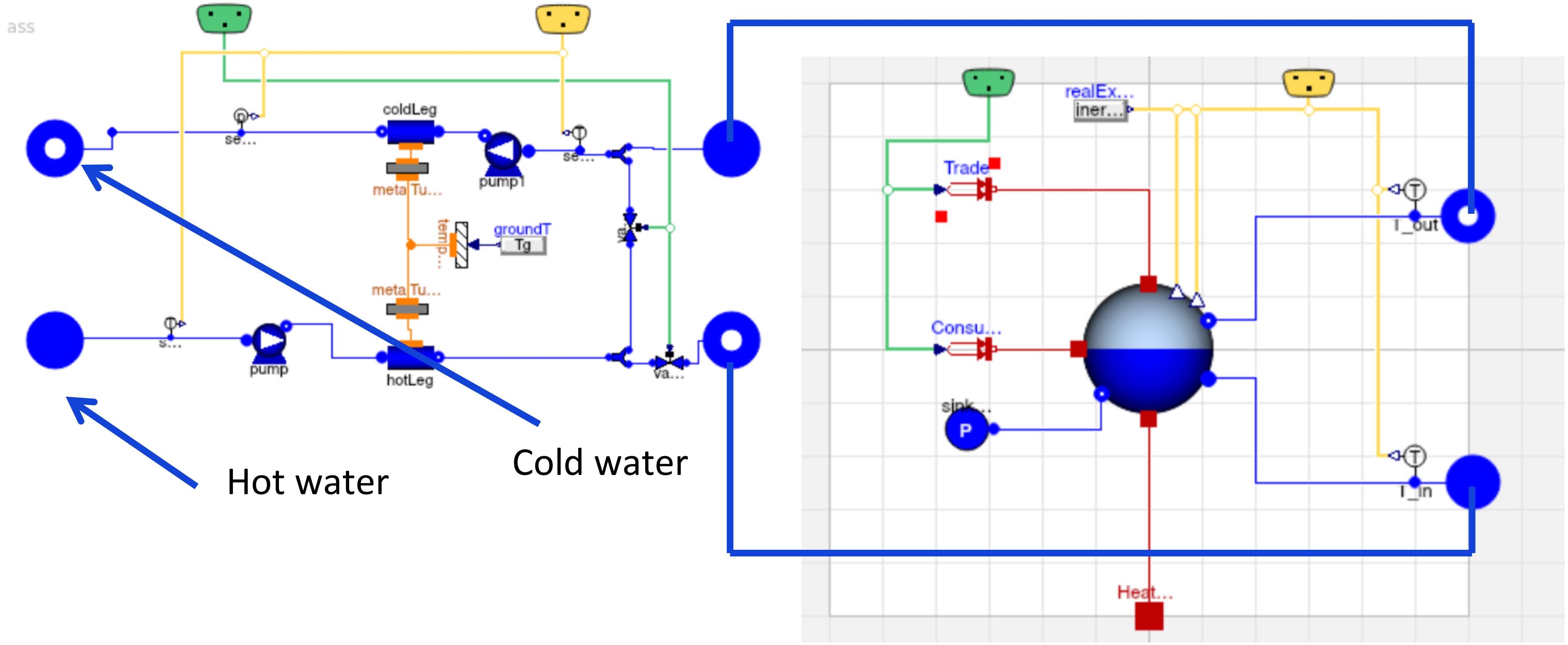
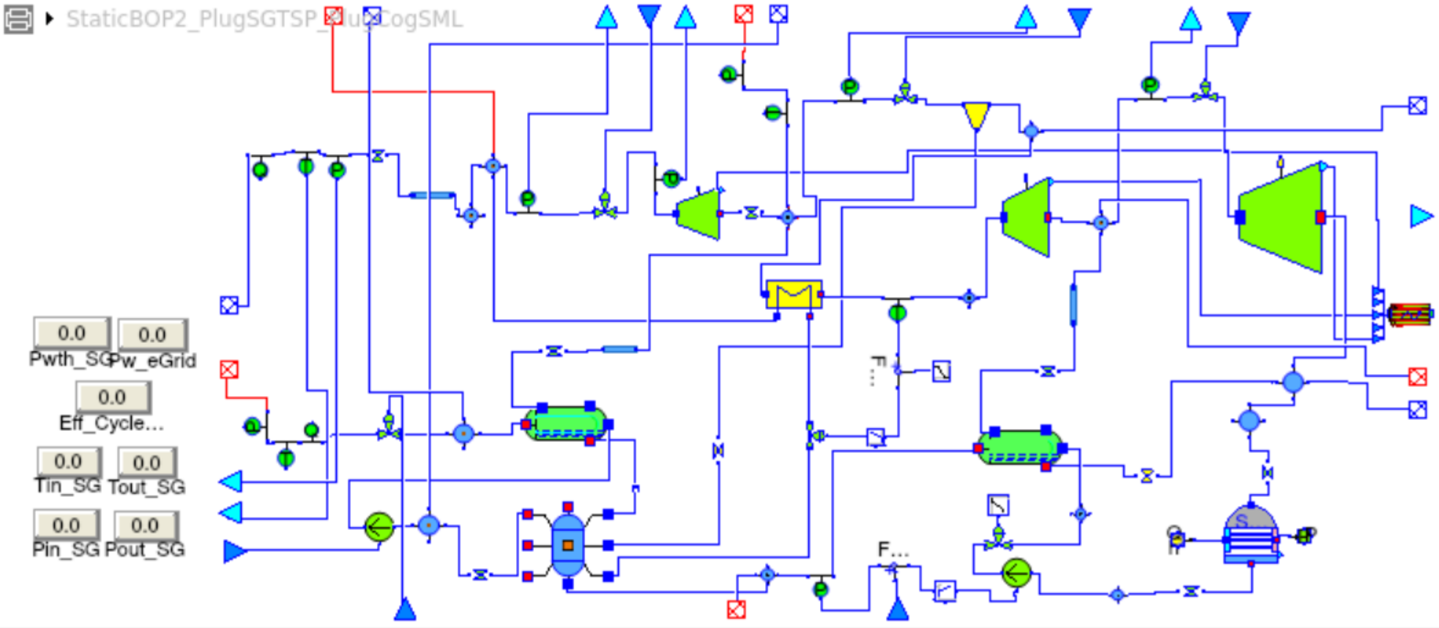


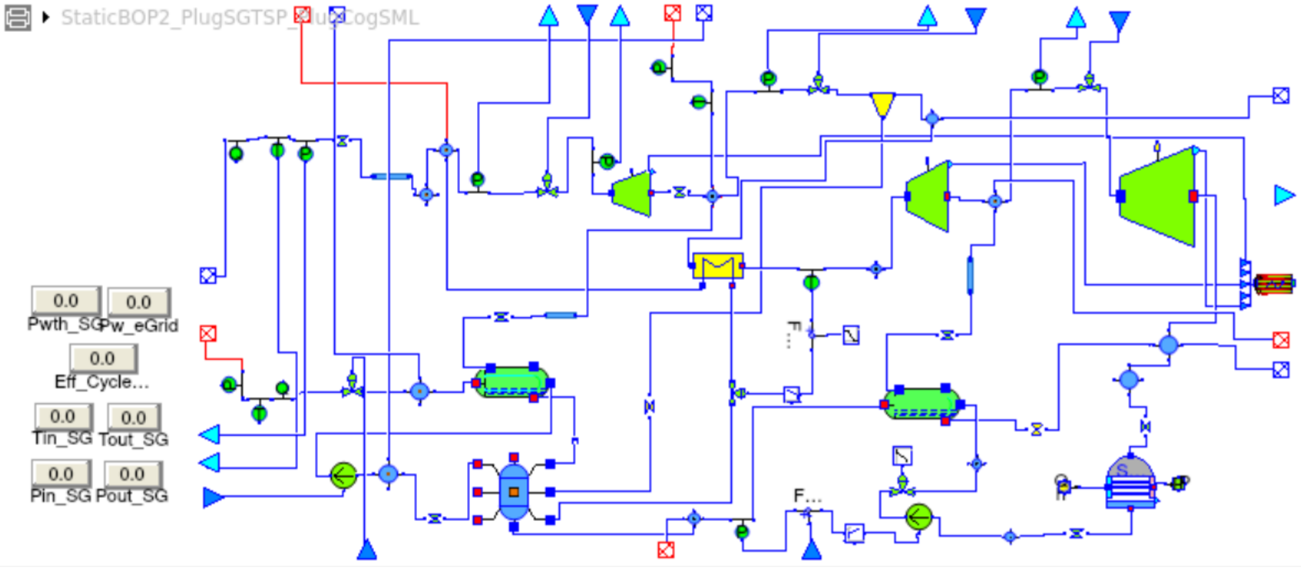
Assigment 3 – District heating

- Identify which is the most suitable connections for the district heating for your NHES. Connect the thermal storage and use the BC to "close" the system



Assigment 3 – District heating

- Hint 1: for feeding the district heating, you want to use relative medium temperature to provide heat through an HX and re-inject before the preheater after the deaerator.



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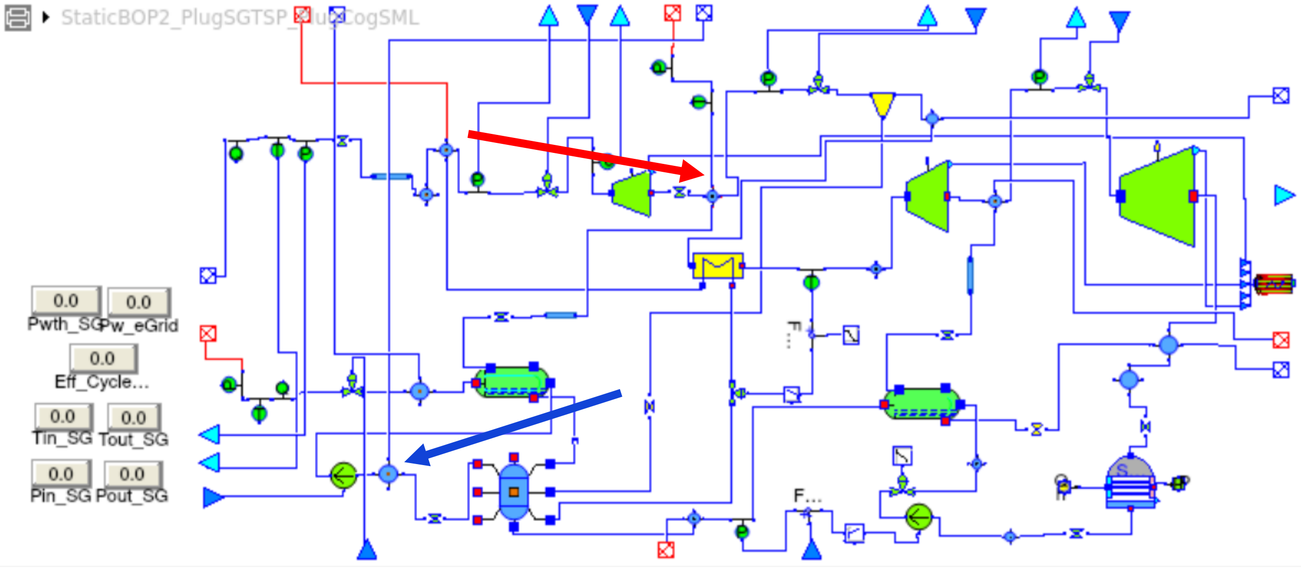

Assigment 3 – District heating

- Identify which is the most suitable connections for the district heating for your NHES. Connect the thermal storage and use the BC to “close” the system

- Run your NHES making a hypothesis about the heat demand. Check the results. Which is the control strategy of the NHES? Comment on that

Assigment 3 – District heating

- Identify which is the most suitable connections for the district heating for your NHES. Connect the thermal storage and use the BC to “close” the system

- Run your NHES making a hypothesis about the heat demand (100 MW). Check the results. Which is the control strategy of the NHES? Comment on that

References

1. P. Fritzson, 2014. Principles of Object Oriented Modeling and Simulation with Modelica 3.3. A Cyber-Physical Approach. Wiley-IEEE Press, 2014, 1250 pages
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3. P. Fritzson, A. Pop, 2020, Introduction to Object Object-Oriented Modeling and Simulation with Modelica and OpenModelica. Tutorial 2020-02-04. https://www.openmodelica.org/images/M_images/200204-ModelicaTutorial-slides-PeterFritzson-AdrianPop-MODPROD2020.pdf

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