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Dynamic modelling of a supercritical coal fired power plant integrated with post-combustion CO_2 capture

3rd Post Combustion Capture Conference (PCCC3)
8-11th September 2015

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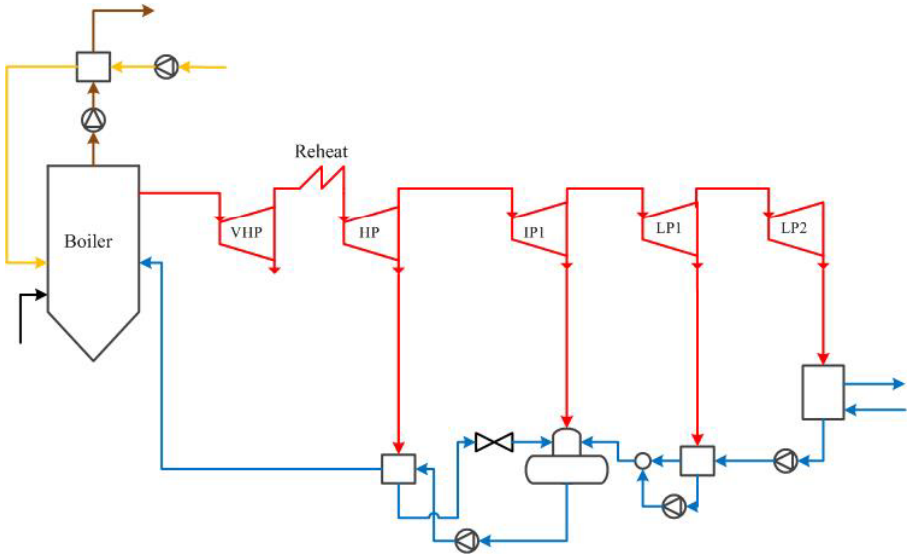
Background

- There is a need for dynamic modeling of power plants with CO_2 capture
  - Dynamic models are useful for improving design, operation and control of new and existing plants
  - Dynamic power plant modelling has been done to some extent but often some important characteristics are left out (e.g. feedwater heaters, steam drum level…)

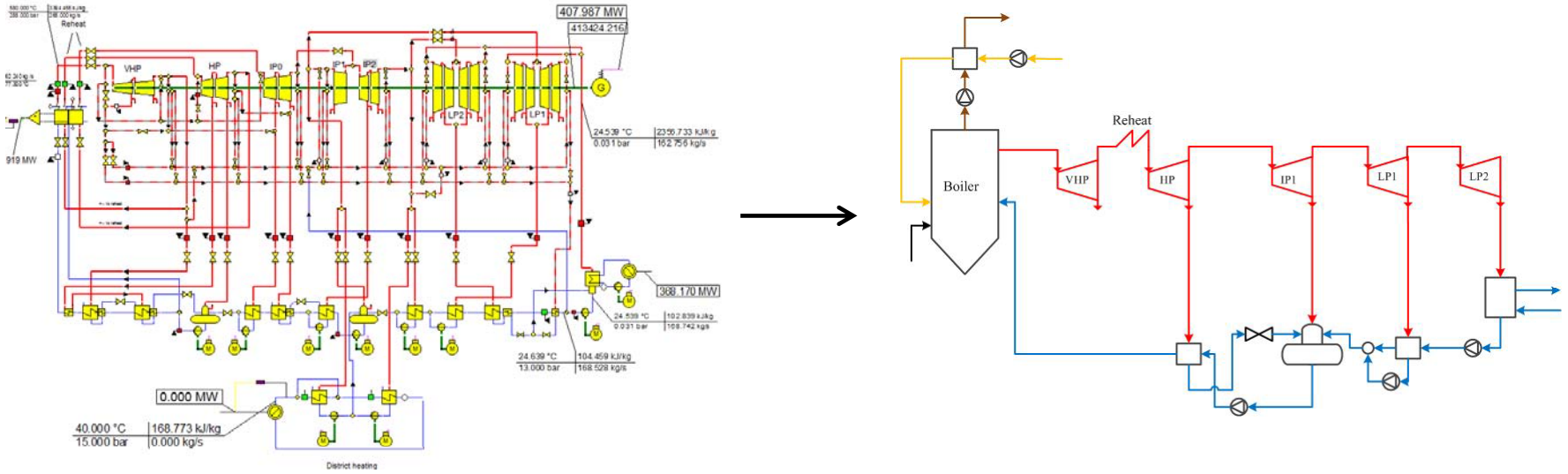


Aim

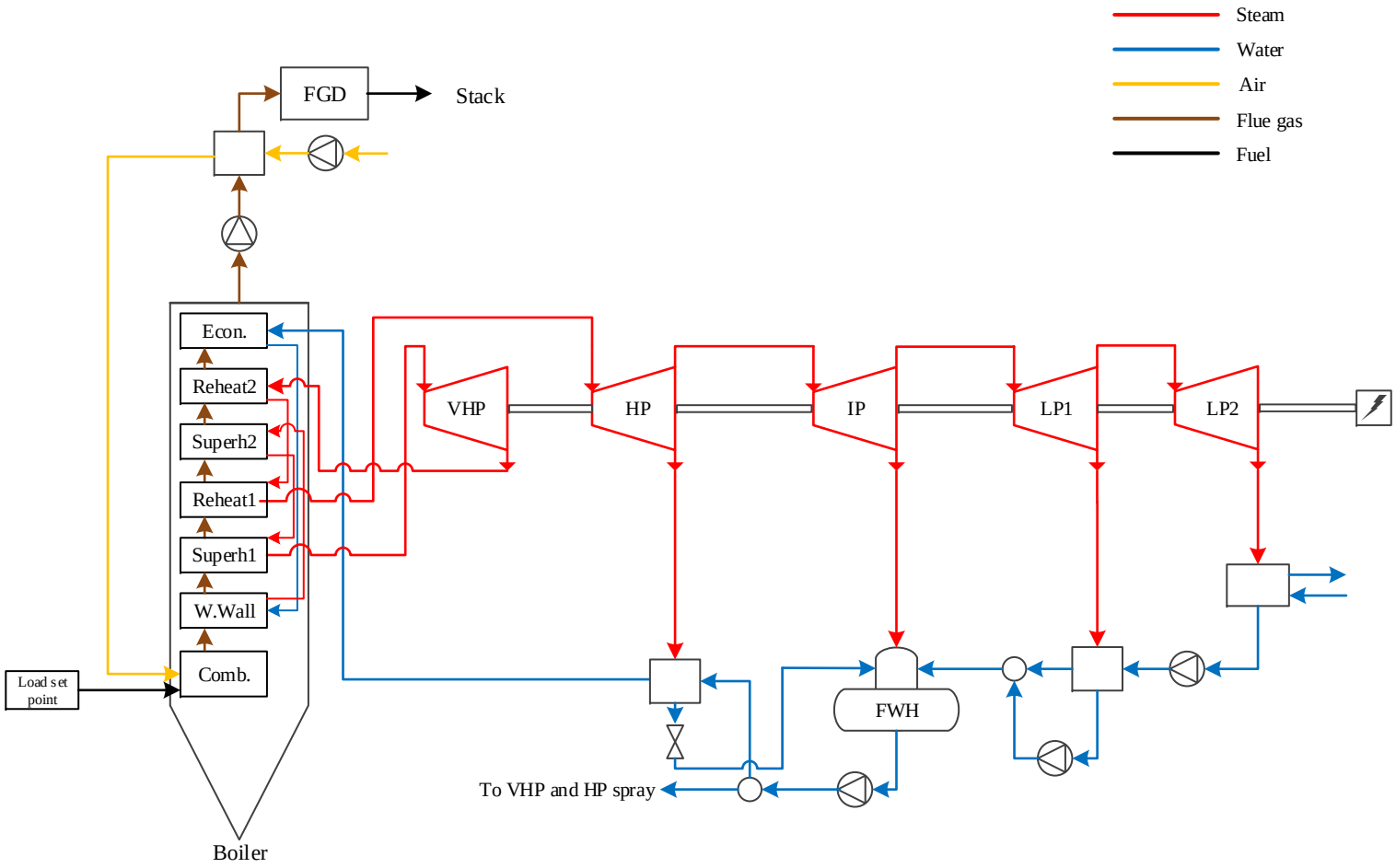
- Develop a simplified representation of a supercritical coal-fired power plant
- Construct a dynamic model of a coal fired power plant according to the simplified design
- Link the power plant model with a model of a post-combustion CO_2 capture (PCC) system from previous work
  - Identify effects of PCC on the power plant dynamics

Steam cycle simplification

- Starting point: Existing detailed steady-state model of Nordjyllandsvaerket power plant constructed in Ebsilon Professional
  - Detailed model validated against plant data

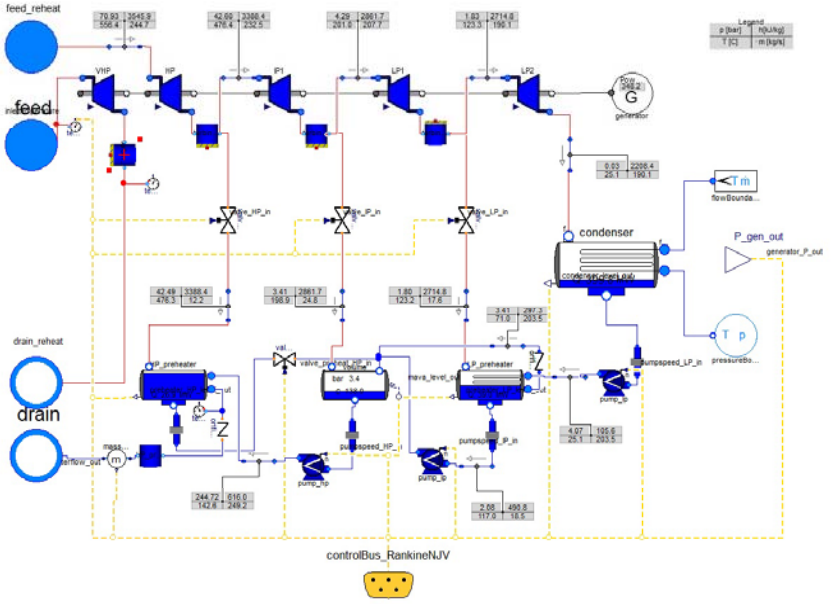


Power plant model overview



Dynamic process modeling

- Dynamic power plant model constructed in Dymola according to simplified design
  - Based on Modelica language (acausal equation based modeling)
  - Components from Modelon's ThermalPower library, the Modelica standard library and custom made components



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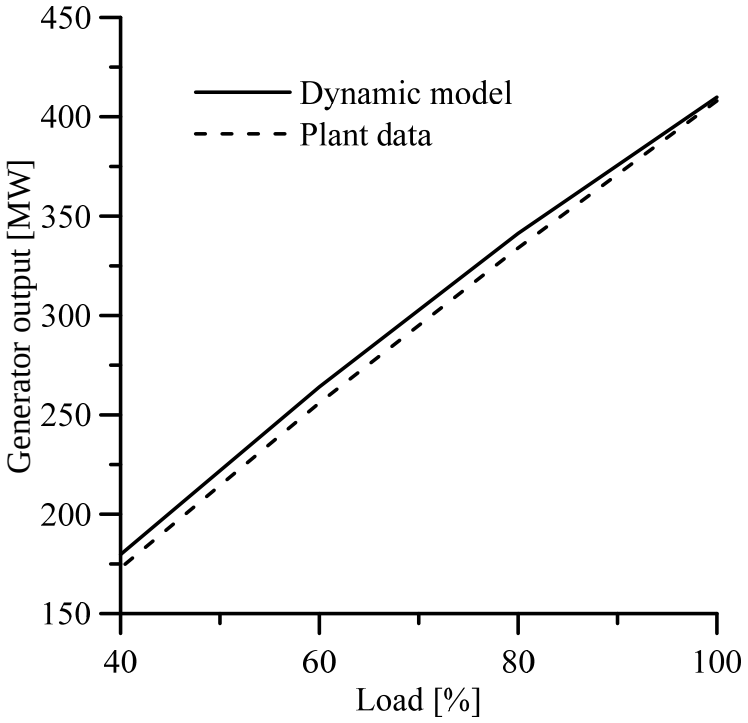
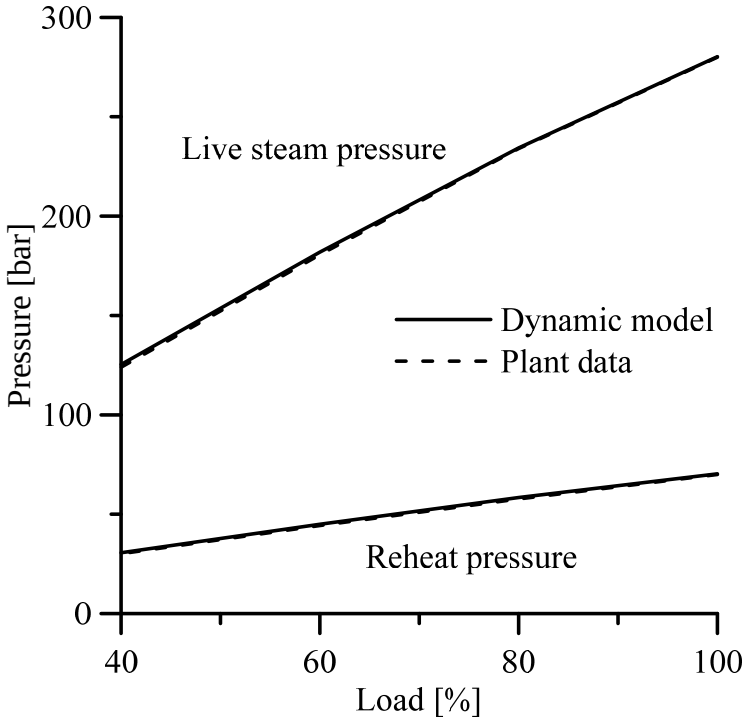
Dynamic model evaluation

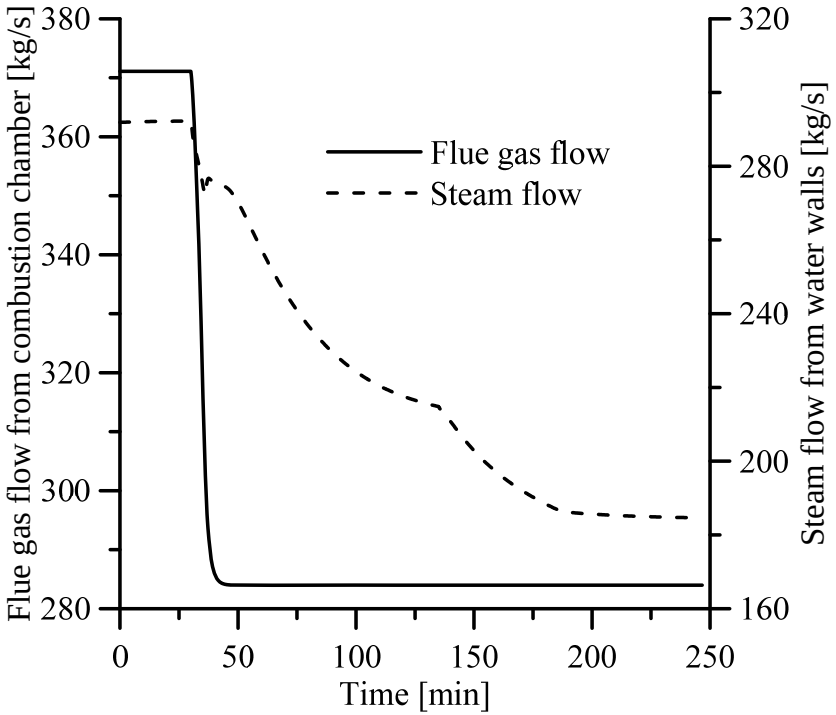
- Steady-state results in Dymola compared with plant data
- Main input to the model is the load curve



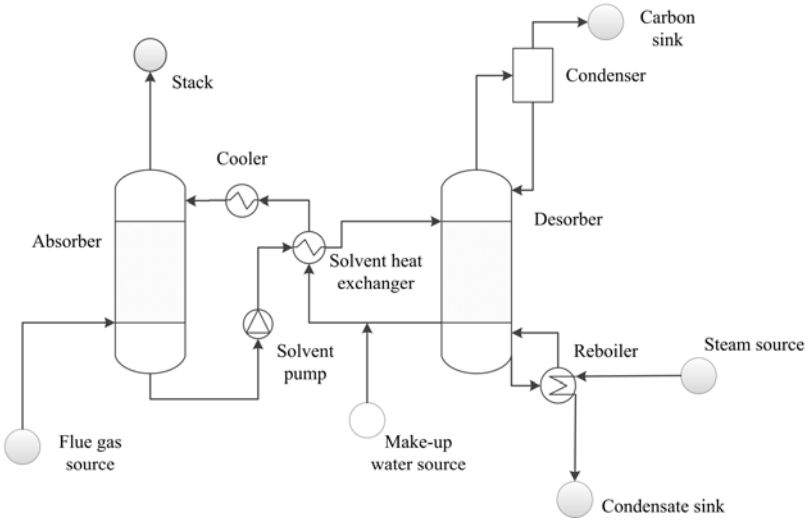


Power plant model – example of results

- **Boiler dynamics – Transition from full load to 70% part load**
- **Load change implemented by ramping down fuel feed rate**
- **Dynamics on gas side very fast compared with the water side**

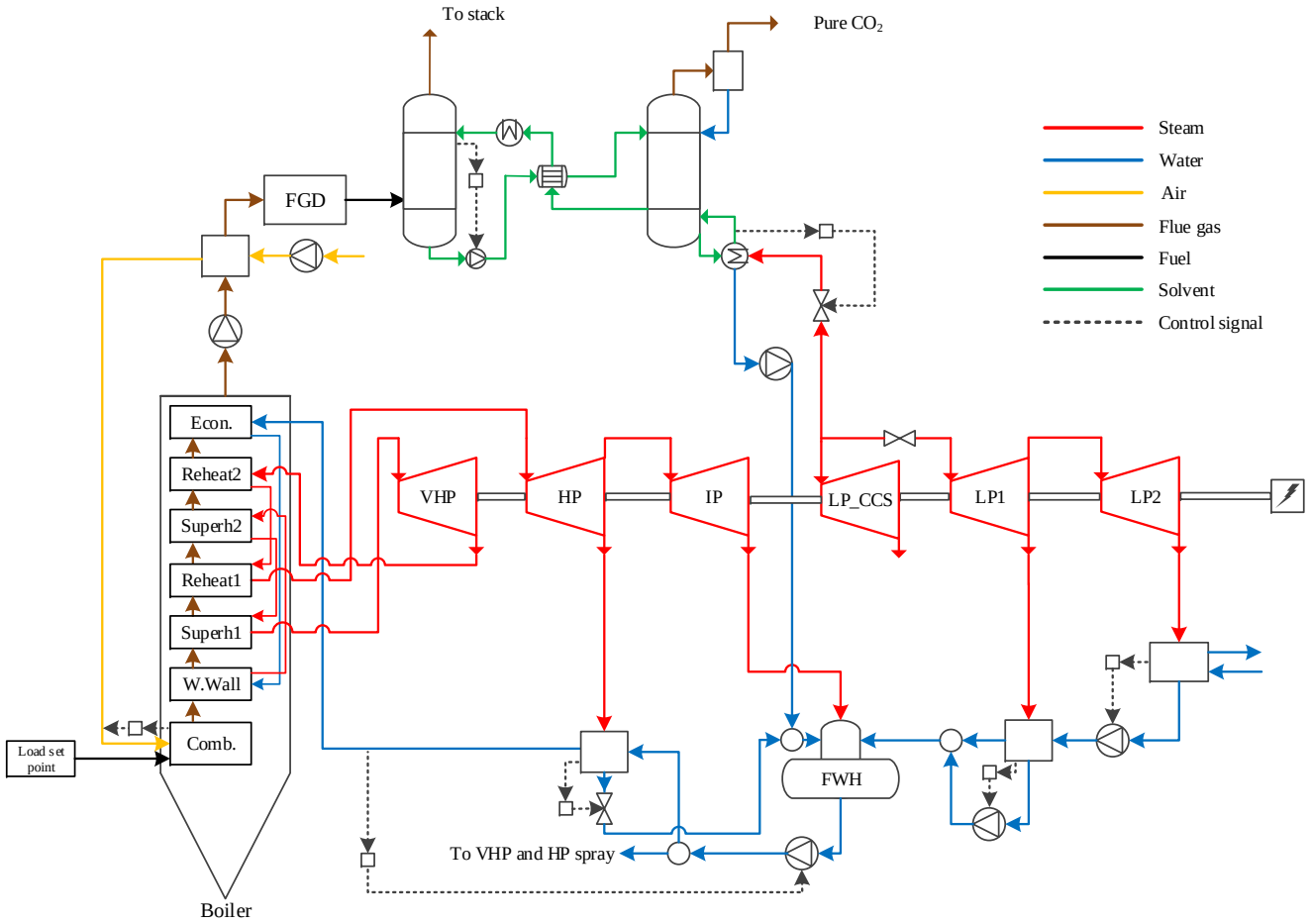


CO_2 absorption model



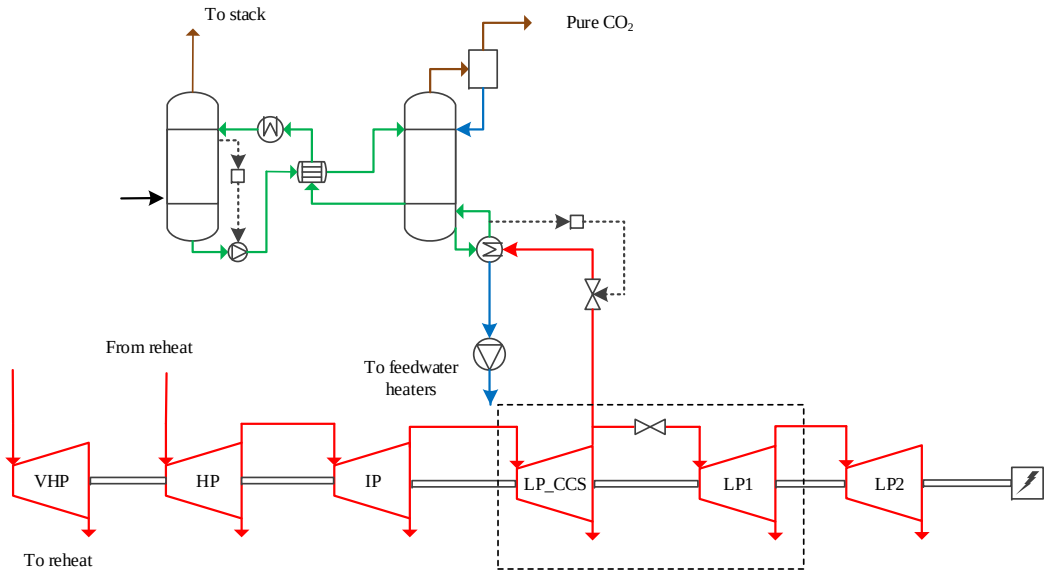
- Rate-based model originally developed by Åkesson et al. (collaboration with Modelon AB)
  - 30 wt% MEA, assumed non-volatile and degradation not accounted for
- Chemical reactions at equilibrium, influence of reaction rates on mass transfer accounted for by using an enhancement factor

System model overview



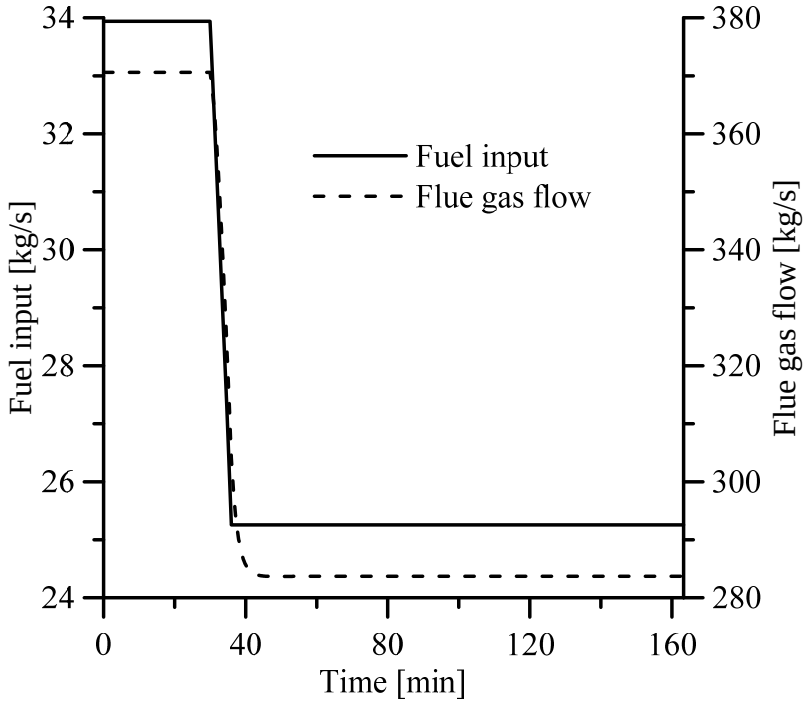
Integration of PCC unit

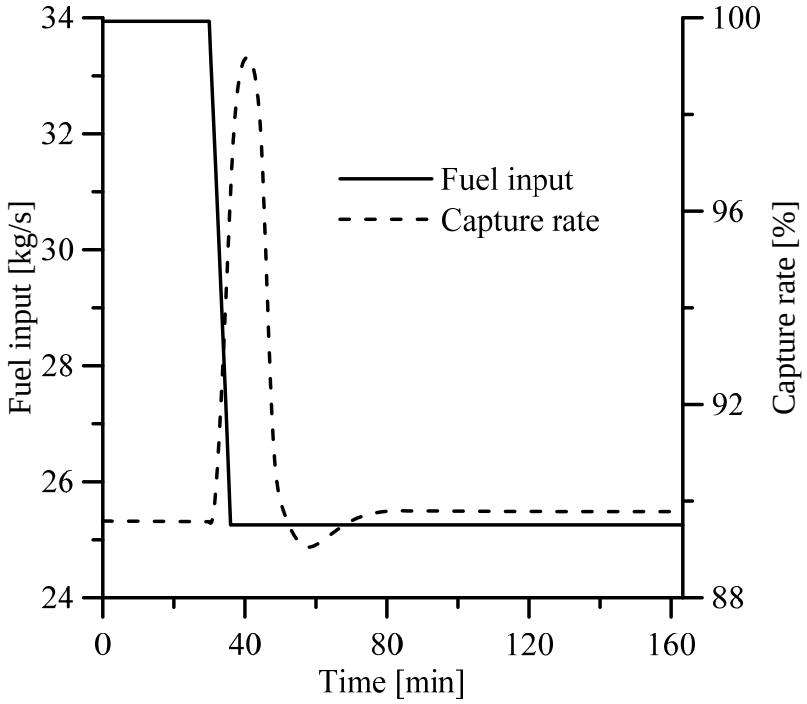
- Steam extracted from an additional extraction point in the LP turbine section
- Extraction pressure maintained at ~3bars in the load range tested by throttling steam between LP turbine stages
- Steam extraction to PCC system affects e.g. mass flows in FWH system
  - Effective control of water levels in tanks and heat exchangers of importance



Preliminary results

Transition from full load to 70% part load
- load change implemented by ramping down fuel feed rate





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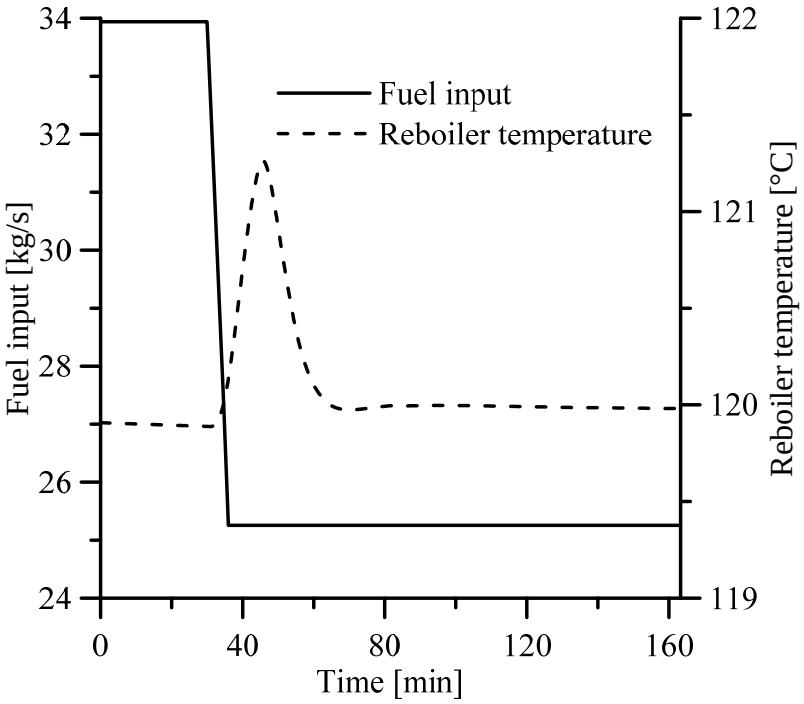
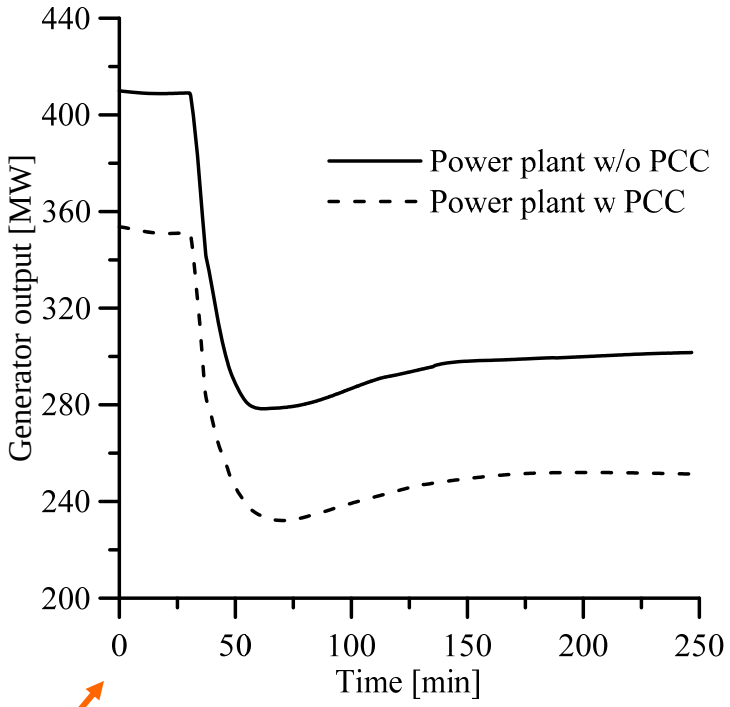
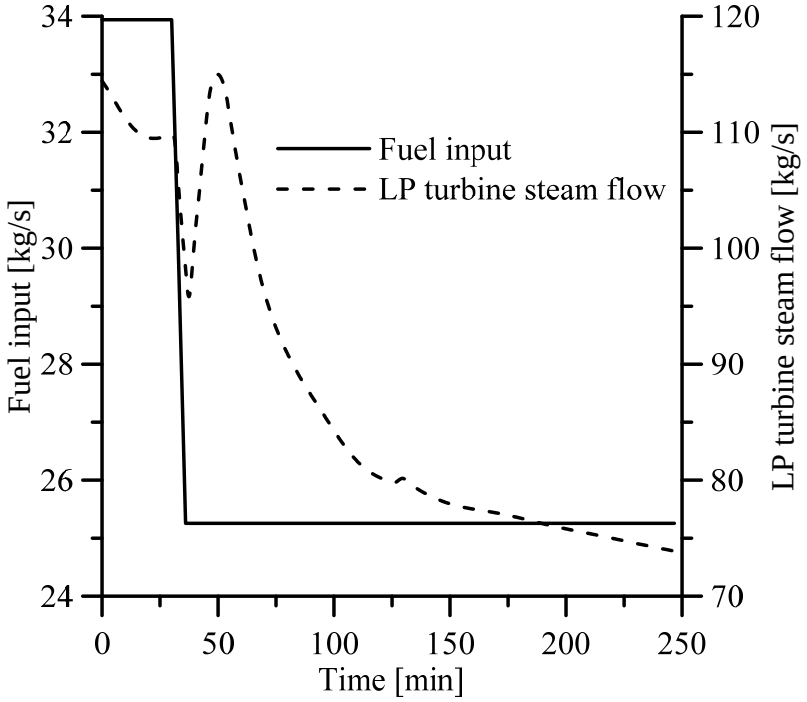




Similar trends, small effects of PCC system?

Preliminary results

Steam turbine limitations – minimum flow and changes in steam quality



Next steps

- Continue with model and scenario development
  - Some adjustments are feasible, e.g. updating mass transfer and liquid hold-up correlations, possible improvements in heat transfer calculations in boiler components
- Collaboration study with Norwegian University of Science and Technology (NTNU)
  - Aiming at investigating effects of integrating PCC unit with coal and gas fired power plants on the power plant dynamics
  - How will the power plants ability to operate flexibly be affected?

Summary

- A simplified steam cycle was designed using the existing Nordjyllandsvaerket coal fired power plant as basis
  - The steady-state performance of the dynamic power plant model is reasonable, compared with plant data
- Data for dynamic validation is scarce, dynamic behavior reasonable?
  - PCC system does not have a large influence on the power plant load ramp rate
- The coupling between the power plant steam cycle and the post-combustion system needs to be carefully designed
  - Flow conditions in LP turbine might prove problematic at low loads

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