Business from technology

Dynamic Simulation and Simulation Tools Development of Oxyfuel-CFB Power Plant

2nd International Workshop on Oxyfuel FBC Technology

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- Development of dynamic simulator for oxyfuel CFB power plant
- Application of the simulator – case examples
- Conclusions

Background

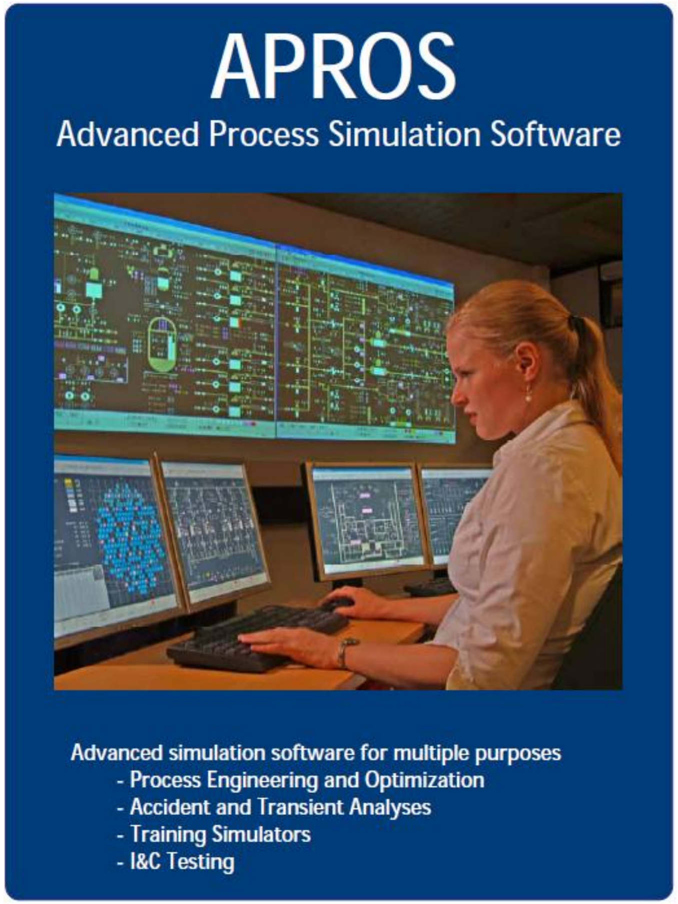
- Typically the development of new concept such as oxyfuel CFB begins with steady state modelling including mass and energy balances etc.
- **Next logical step is a analysis of process dynamics for the developed concepts**
- Currently only few comprehensive dynamic process models for the integrated oxyfuel CCS have been published → dynamic models for separate sub-processes such as ASU and boiler have been presented widely
- Compared to steady sate process models a lot of detailed information is needed to build up (accurate) dynamic process model
- **Iteration between steady state and dynamic modelling is needed to develop fluent concept before the large scale demonstration**

Objectives for the development of the dynamic simulator

- The primary target is to provide information on dynamic behaviour of the **integrated** system
    - This information is essential for verifying the feasibility of the process concept and its control strategies from low level to upper level controllers
- Operability of the novel concept must be studied and guaranteed before large investment in demonstration unit
- Solid understanding of the plant dynamics is needed to develop advanced high level controls
    - Dynamic simulation supports this task by providing dynamic response data for required variables

Selection of software (1/2)

- In general, adequate simulation tool is not always available
    - Tools need to be integrated
- The APROS simulation tool provides easy on-line access for configuring and running the simulation models, solution algorithms and model libraries for full-scale modelling and dynamic simulation of processes, such as combustion power plants and nuclear power plants
- The model libraries have been comprehensively validated against data from physical process experiments
- www.apros.fi



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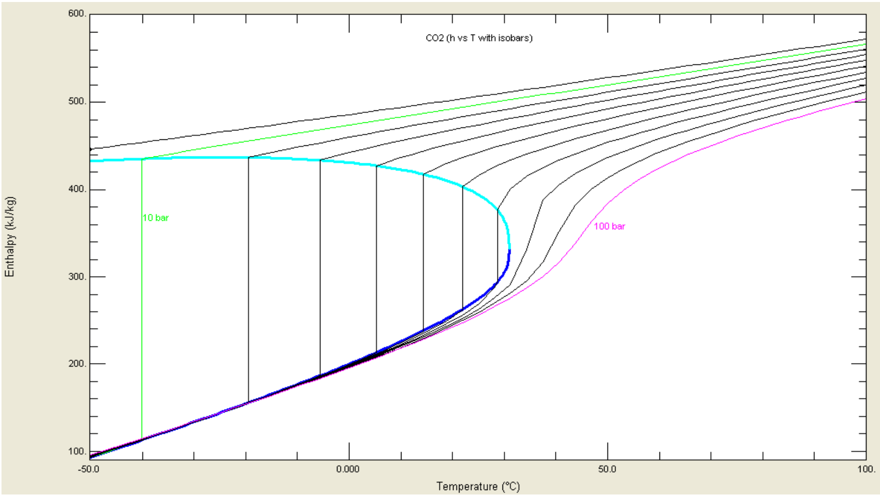
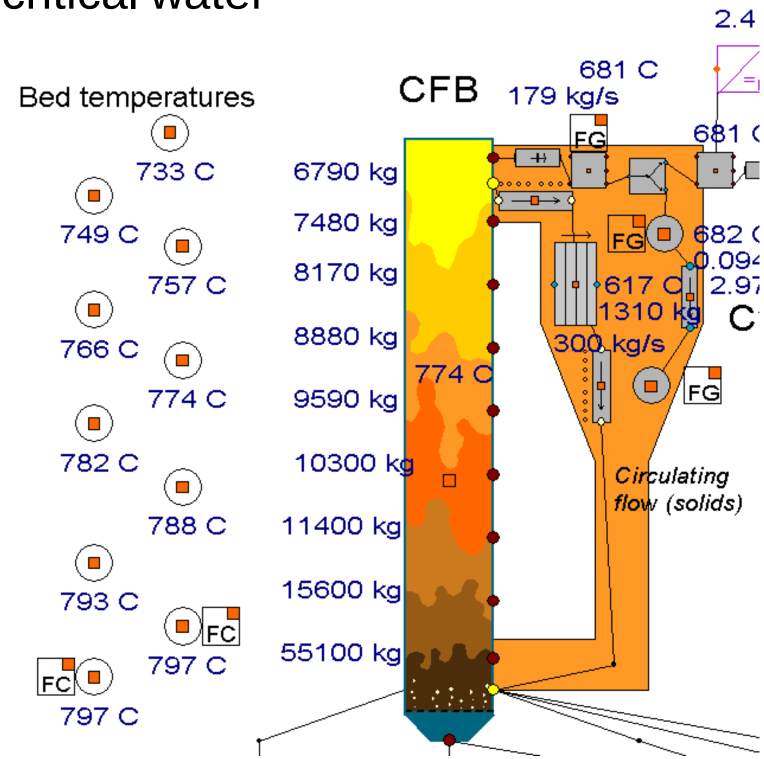
Selection of software (2/2)

- **Aspen Plus® Dynamics** is a very powerful tool to model chemical processes such as distillation processes needed for oxyfuel CCS plant
- Objective was to combine the best part of the softwares (Apros and Aspen Plus Dynamics) in order to simulate the modern process concepts with the best possible tools
  - Power plants with APROS
  - Chemical plants with Aspen

Simulation platform developments in APROS

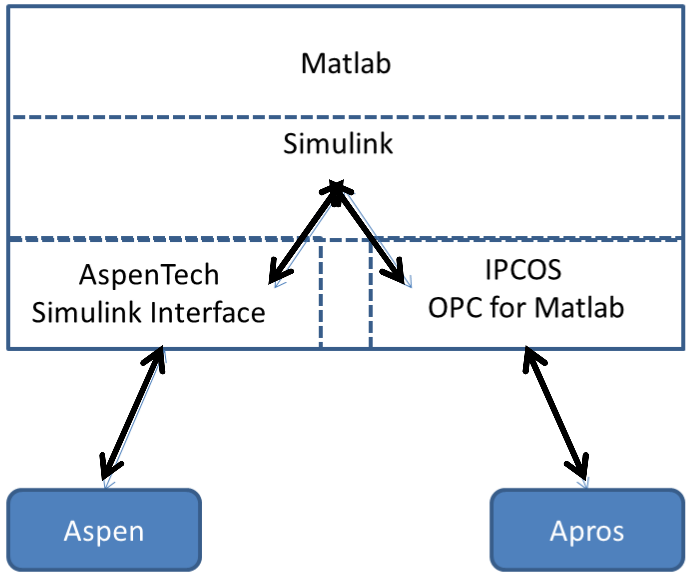
- FLEXI BURN CFB project utilizes several recent developments
- Thermal hydraulics
  - New fluids for homogeneous model pressure-flow solver: CO_2, N_2, O_2, air
  - Improvements to 6-equation model and supercritical water
- New unit operation models
  - Circulating Fluidized Bed
  - Particle transmitter (solid material recycling)

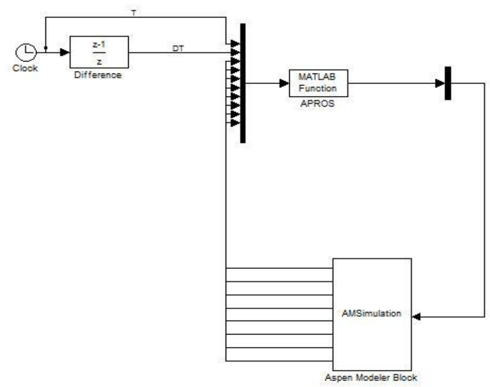




Integration of softwares

- Several connection methods evaluated
  - ➢Direct OPC, Excel, Matlab
- Evaluation based on
  - ➢Synchorization possibilities of simulator
  - ➢Ease of configuration
- Chosen method
  - ➢Combination of OPC and Matlab





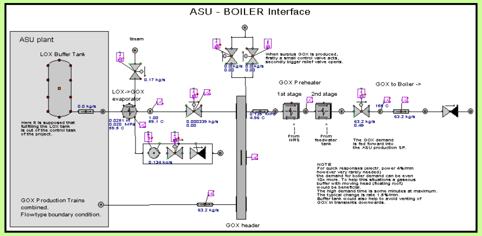
Development of dynamic simulator

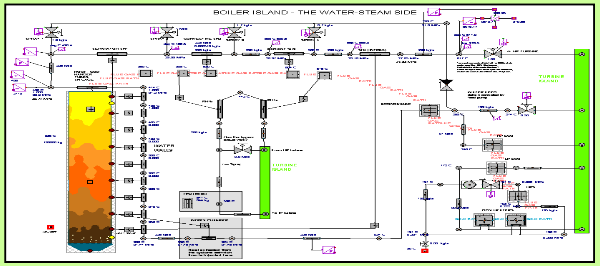
- A dynamic tool combining Apros and Aspen Dynamics simulators of the process integrate that covers ASU (Air separation unit), CFB (circulating fluidized bed boiler) with turbine Island, and CPU (CO2 compression and purification unit) was developed
- The model includes the main process units and streams of the process to provide the characteristic dynamic features of the system
- The **control loops** and supporting calculations that were essentially required to operate the system are included

A dynamic tool combining Apros and Aspen Dynamics simulators

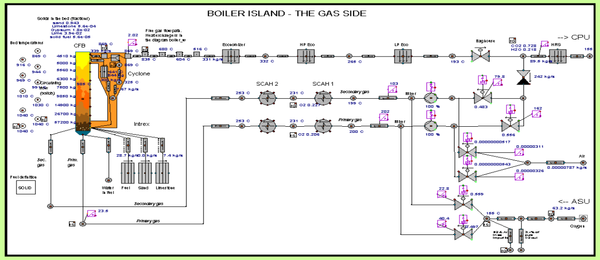
- Neither tool alone was able to simulate the entire ASU + CFB + CPU process **in detail** ➔ combine the two

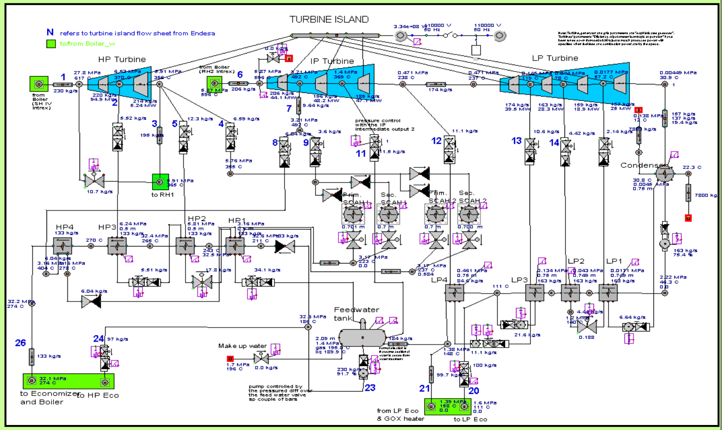
APROS





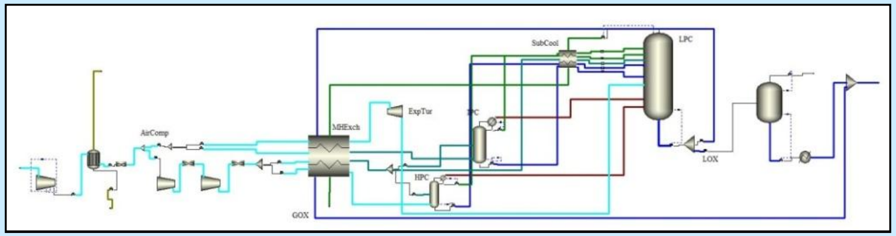
CFB boiler unit



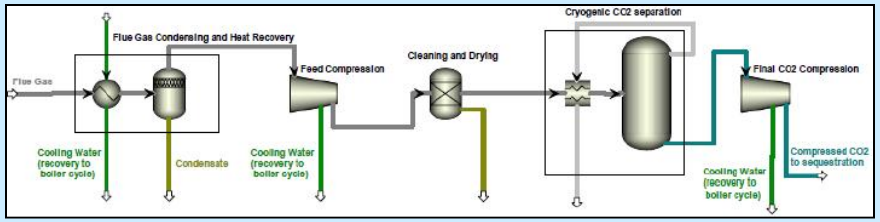


Turbine and water cycle

ASPEN PLUS DYNAMICS



Air Separation Unit



Carbon compression and PurificationUnit

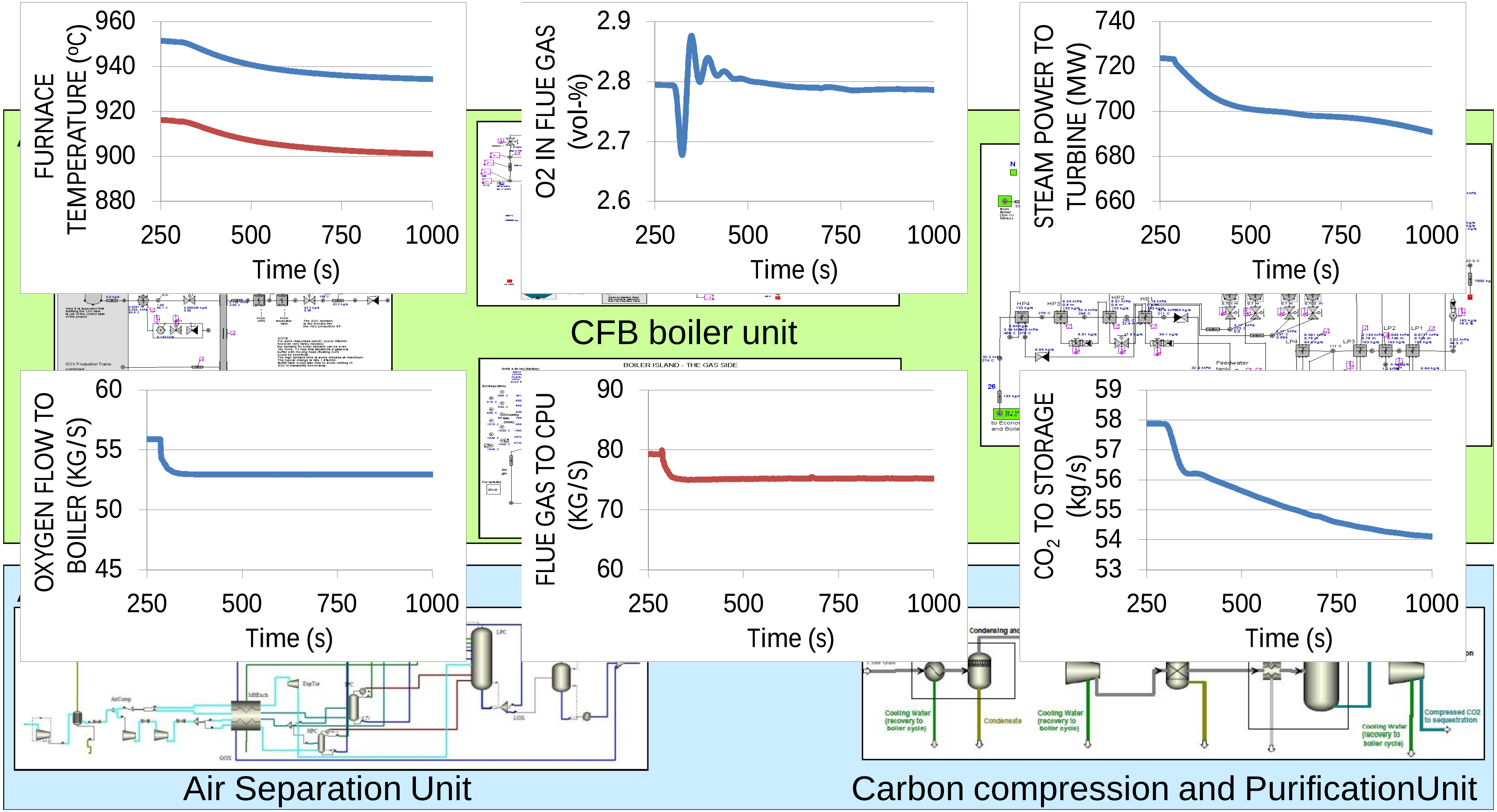
Dynamic simulation of oxyfuel CFB power plant

- Typically simulation studies include operation transients, such as
  - start-up and shut-down,
  - load changes,
  - various disturbance situations,
  - changes between air- and oxygen-firing
- Comparison and analysis of air- and oxygen-firing in above mentioned situations
  - special features of oxygen-firing e.g. effect of high flue gas recirculation on boiler behaviour and control system
  - coordination and upper level controls for the integrated power plant including ASU, boiler and CPU

SIMULATION EXAMPLE 1:

LOAD CHANGE -5%

Simulation example – load change -5%



SIMULATION EXAMPLE 2:

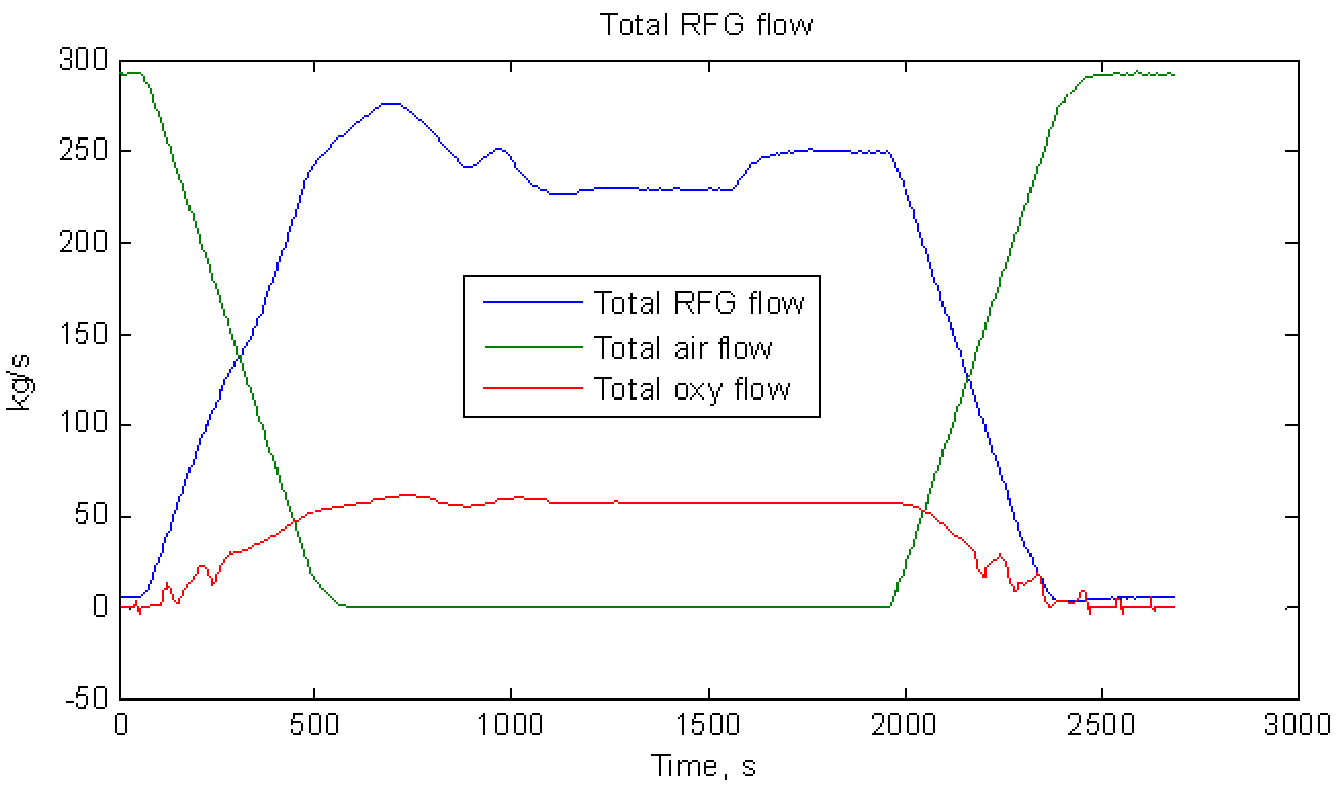
MODE CHANGE FROM AIR TO OXY AND BACK

Simulation example: Mode change from air to oxy and back

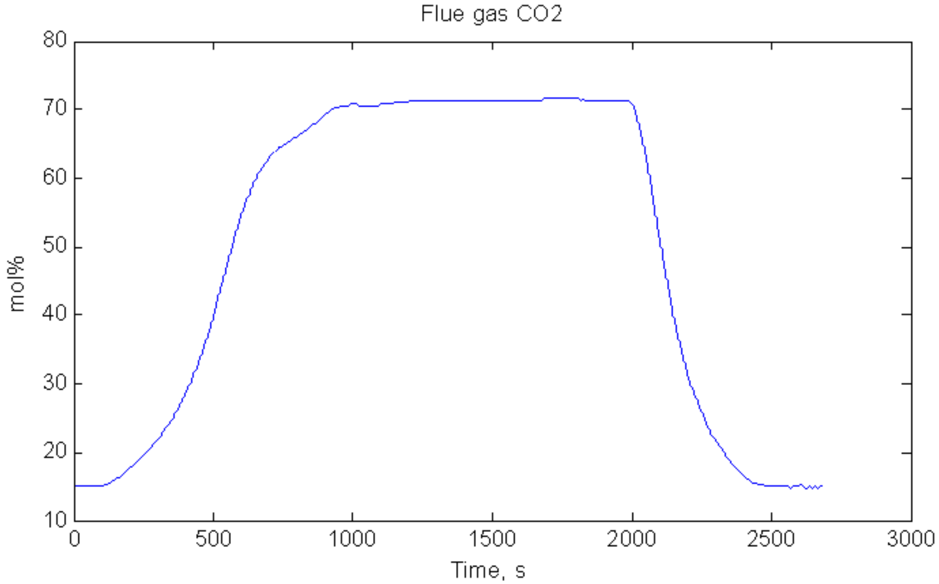
- Mode change from air mode to oxy mode and back again
- The manipulated variables:
  - Air flows
  - Oxygen flows
  - RFG flows
  - (Fuel feed is constant)
- During the changes all the set points for primary air, secondary air, primary RFG-gas secondary RFG-gas, primary oxygen and secondary oxygen flows are ramped up/down with same ramping rate
- Duration of transitions about 9 min

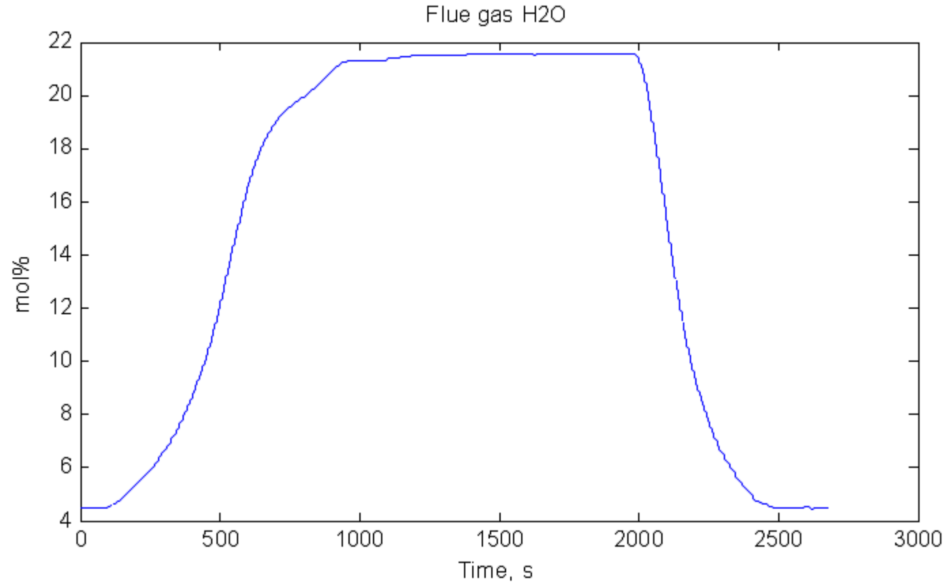
Simulation example: Mode change from air to oxy and back

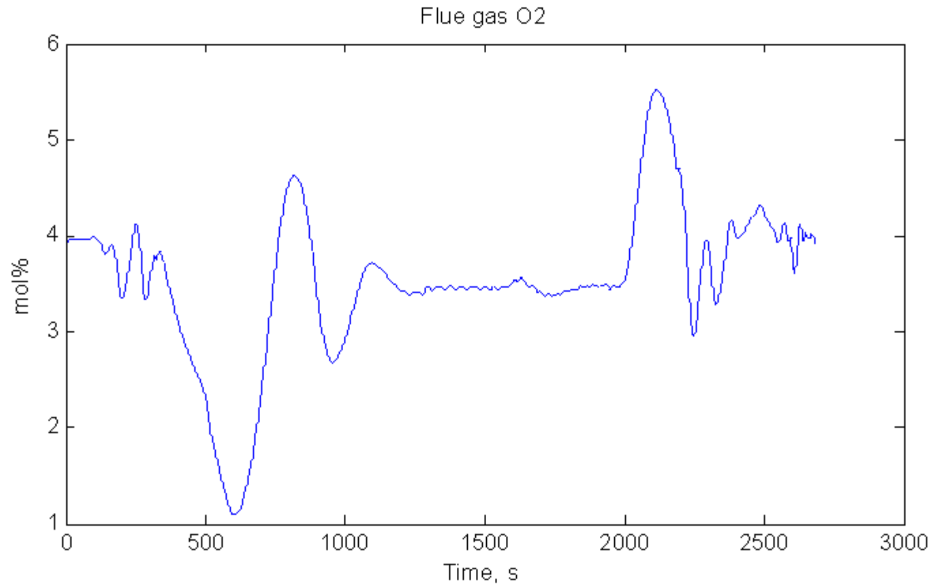
Simulated gas flows during combustion mode change

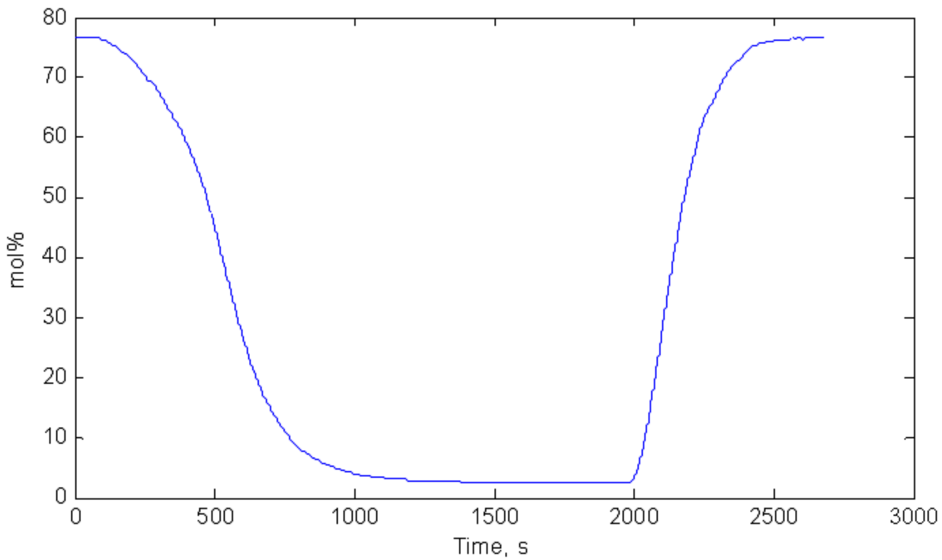


Simulation example:
Mode change from air to oxy and back: emission responses









Conclusions (1/2)

- Time dependent process model was developed for Oxyfuel CFB power plant including ASU, boiler island and CPU
- Simulation of the concept with best possible tools
    - Power plants with APROS
    - Chemical plants with Aspen
- The model performance was tested by simulating load changes and transitions between air and oxy modes
- The model provides excellent base to study dynamical behaviour of the oxyfuel CFB power plant with CCS and **to develop and optimize control strategies, upper level controls, and operational practises**

Conclusions (2/2)

- Dynamic simulation of the **integrated** oxyfuel CFB power plant with CCS is very important in order to guarantee high availability combined with high efficiency and safety operation
  - e.g. the interface between ASU and the boiler island proved to be very important part of the system from control and operation point of view
- Further development of oxyfuel CCS concepts call for dynamic simulators
  - e.g. development of **the second generation of oxyfuel CFB power plant concept** with significantly higher efficiency

Future developments in simulation tools

- Need to improve integration of different simulation tools e.g. ASPEN and APROS without matlab link
- Further development of submodels for ASU, boiler and CPU

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