Total chain dynamical assessment with an integrated model of a Post Combustion Capture Plant at a Pulverized Coal Plant and CO2 downstream infrastructure.

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ABSTRACT

Introduction
The application of Post Combustion Capture has a significant advantage for mitigating the anthropogenic greenhouse gases in our atmosphere, in comparison to other capture technologies, since it is a so called “End of the Pipe” retrofit and therefore potentially applicable to existing power plants. With a fast changing power market and a significant portion of renewable energy, the operational flexibility is becoming imperative aspect for power plants. It is worth noting that the value of a power plants will be increasingly determined by its operational capabilities in providing swing power and high commercial availability and reliability. The application of post combustion capture technology might provide an additional operational flexibility by running the capture unit at different part load or on/off. Nevertheless there is absence of operational experience with a post combustion capture technology at a scale of 200 MWe (equivalents) which is approx. 1,2 Mton/year of CO2 captured. Advanced dynamic simulation will provide more insight in operational flexibility and bottlenecks and will cover the lack of knowledge to properly asses the significant scale-up step of Post Combustion Capture technology. In view of the entire chain, operational constraints from the downstream CO2 infrastructure and power plant integration (e.g. steam) are for the demonstration projects top ranked risk (uncertainty) which must be mitigated.
A detailed dynamic simulation model of an absorption/desorption process has been developed, which has been validated and calibrated with pilot plant data from the TNO post combustion pilot plant at EON premises. To assess the pilot plant dynamics, open-loop step response tests are performed in which the flue gas flow rate and the lean solvent flow rate are disturbed. The used solvent during these tests was a 30 wt.% monoethanolamine (MEA) solution. The objective of the validated dynamic model is to address the knowledge gaps for the large scale demonstration projects and provide a tool for: process optimization, to design the process control base layer control blocks and supervisory process control algorithms for the interfaces of the entire CCS chain form source to sink.

Modeling
For the modeling of the dynamic behavior of the CO2 infrastructure, point kinetics (lump sum) models are used. Property data banks are used to calculate the thermodynamic behavior of a gas mixture or liquid mixture. An equilibrium based approach is carried out as modeling the transients is of higher importance than very accurate steady-state results. As such our tools are based on typical empirical relations (validated) and the thermodynamic postulates.

Computer tools used are Modelica® and Dymola. Modelica® is a non-proprietary (open), object-oriented, equation based language to conveniently model complex physical systems containing, e.g., mechanical, electrical, electronic, hydraulic, thermal, control, electric power or process-oriented subcomponents.
The Dymola environment uses the open Modelica® modeling language which means that we are free to create our own model libraries, property databases and or modify available model libraries to match the unique modeling and simulation needs required for CO2 application and power plants. The flexibility of Dymola makes it a versatile tool which is perfect for modeling and simulation of new alternative designs and technologies within the field of CCS.

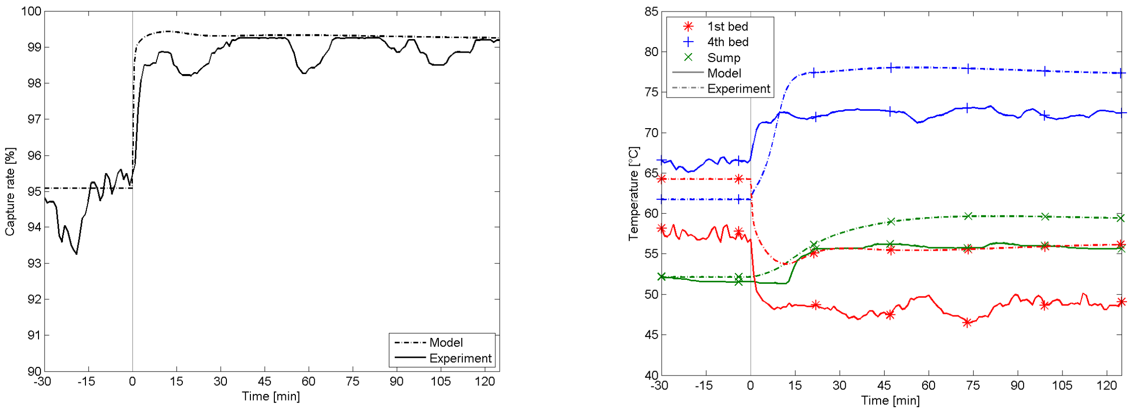

Figure 1: comparison of the step response of the pilot capture plant model and the experiment of the capture rate (left) and the absorber temperatures (right) for a step decrease in flue gas flow rate at time=0

Results and discussion

The model has been successfully validated with pilot plant data and provides at this stage of development already interesting observations such as the water balance, stripping steam integration requirements. Variables used for validation were the capture rate, the absorber temperatures and the CO_2 loading of the solvent leaving the absorber and stripper column. Although steady-state values do not match (see figure 1), it can be concluded that the model shows similar responses in terms of time scale and gradient. Currently, the model will be expanded, as such that constraints from the downstream processes can be scrutinized e.g. the minimal flow conditions of the well or the dense phase transport of CO2. Next to this the integration with a power plant will be expanded in more detail to address in a comprehensive way the steam and flue gas integration of the Post Combustion Capture System.

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