Modelling of Ca-looping for a 250 MWe lignite coal fired power plant

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Abstract

This paper presents a comprehensive model of a Ca-looping CCS system that is applied on a reference conventional lignite coal fired power plant that shall be implemented by a CO₂ capture system. The gross electric power output of the reference plant is 250 MWe, with coal consumption 214 t/h and corresponding CO₂ production 211 t/h. Net electricity production of the power plant is 226 MWe and net electric efficiency before CCS application is 38.4 %.

The general model of the power plant balance is extended by a detailed model of the Ca-looping system, consisting of two separated models of carbonator and calciner. The model of a circulating fluidized bed type carbonator is the main part of the model and comprises of modelling the fluidized bed hydrodynamics and the chemistry of the CO₂ reaction with the limestone sorbent. The most complicated fluidized bed hydrodynamics is solved on the basis of using various available sub-models that are modified and compiled for the needs of the carbonator model. Two different sorts of limestone are supposed in the model, both in mean particle size 250 µm. The sorbents are particularly different from the point of purity (99 % CaCO₃ vs. 75 % CaCO₃) and laboratory-determined sorption capacity (37 vs. 6 g CO₂/100 g of the sorbent). The result of the numerical model of the carbonator is a general dimensioning of the carbonator system, parametrized for the different required CO₂ capture efficiencies at levels 70, 80 and 90 %. This parametrization is the basis for calculation of flows of the main gas and solid streams, for the heat production and consumption assessment and for calculating composition of the outgoing flue gas. The model also considers a competitive reaction of the sorbent with sulphur dioxide.

Significant attention has been paid to estimation of decrease in the sorption capacity after several carbonation-calcination cycles. In the numerical model there is implemented a theoretical approach acquired from the literature that is compared with the real data measured in the laboratory, using real samples of the sorbents. From the study of carbonation reaction in laboratory the reaction rate constants were also determined and they replaced the literature-based data in the original model. The calcination of the samples in laboratory was carried out at 1000°C in inert atmosphere (N₂) and carbonation at 650°C and atmosphere 86 % N₂ + 14 % CO₂.

The calciner model is considered as an oxyfuel coal-fired CFB combustor. The same sort of coal is considered for combustion in the calciner. The other ballast flows are therefore included into the model, e.g. ash content in the coal. The calciner model is based on heat balance of the oxyfuel
combustor extended by the heat consumption of the calcination reaction and calcination chemistry in the oxyfuel mode.

Final output of the numerical model is, besides dimensioning of the system, assessment of impact of the Ca-looping integration into conventional power plant. The assessment includes balance design of a HRSG for heat recovery from the CO$_2$ leaving the calciner for electricity production, evaluation of internal electricity consumption of the Ca-looping capture system and evaluation of overall energy impact on the power plant.