MODELLING AND SIMULATION OF A COAL-FIRED SUPERCRITICAL POWER PLANT INTEGRATED TO A CO₂ CAPTURE PLANT

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Abstract:

The reduction of solvent regeneration energy is the focus of most of the solvent-based post-combustion CO₂ capture (PCC) research currently being performed globally. From the viewpoint of current research and development (R&D) activities worldwide, three main areas are being investigated in order to reduce the regeneration energy requirement of amine-based PCC, namely: (a) development of new solvents with better overall performance than 30 wt% monoethanolamine (MEA) aqueous solution, which is generally considered as the base-line solvent for solvent-based PCC, (b) PCC process optimization, including modifications of PCC plant configuration, and (c) optimal integration of the PCC Plant, including the associated CO₂ compression system, to the upstream power plant.

Process modelling and simulation is critical in the optimal scale-up of a PCC pilot plant to the size required for a commercial-scale coal-fired power plant. In this work, an integrated process comprising a 550MWe pulverized coal-fired supercritical power plant, an MEA-based PCC plant, and a CO₂ compression train, has been modelled and simulated. The coal-fired power plant has a coal-fired boiler incorporating a selective catalytic reduction (SCR) unit for NOx reduction, a wet lime-based flue gas desulphurization (wet FGD) unit for Sox reduction, an ESP for particulates removal, and a supercritical steam cycle with single reheat. The PCC plant has two absorber columns and a single stripper column while the CO₂ compression system is a six-stage compressor with inter-stage coolers.

The modelling and simulation was realized with Aspen Plus® V8.4. The boiler, the steam cycle and the CO₂ compression system were modelled based on a 2010 US DOE report as well as a 2004 IEA report, while the MEA-based PCC plant was modelled as a rigorous rate-based process. The scaling of the amine plant was performed using a rate-based calculation as against the traditional equilibrium based approach for 90% CO₂ capture; thus, the scaling of the PCC plant was optimized and unnecessary over design of the PCC columns was avoided.

The power plant was integrated to the PCC plant in three ways: (i) the boiler flue gas to the PCC absorber, (ii) the steam tapping from the IP turbine-LP turbine cross-over in the steam cycle to the PCC reboiler and (iii) the condensate return from the PCC reboiler to the steam cycle deaerator. Extensive simulations of the integrated process using different types of coal have been performed and the impacts of coal type on the overall performance of the process have been quantified.

Keywords: Coal-fired, Power Plant, MEA, CO₂ Capture, Modelling, Simulation

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