DESIGN AND OPERATIONS OPTIMIZATION OF MEMBRANE SEPARATION FOR FLEXIBLE CARBON CAPTURE FROM NATURAL GAS COMBINED CYCLE SYSTEMS

Mengyao Yuan, Department of Energy Resources Engineering, Stanford University
yuanmy@stanford.edu
Holger Teichgräber, Department of Energy Resources Engineering, Stanford University
Adam Brandt, Department of Energy Resources Engineering, Stanford University

Key Words: Optimization, flexible carbon capture, membrane separation, natural gas combined cycle, renewable energy integration.

We explore the concept of flexible carbon capture using membrane separation. Flexible carbon capture has been studied in recent years as a measure to decarbonize fossil-fired power generation in response to electricity market conditions, including varying electricity prices and/or fluctuating electricity supply requirements. The importance of flexible operation of carbon capture systems is highlighted by the increasing penetration of intermittent energy generation from renewable sources such as wind and solar PV.

To accommodate the integration of renewable energy into the grid, fossil-fired power plants would need to generate varying electricity load, producing flue gas with varying characteristics and at varying volumes. Carbon capture systems in a high-renewables grid will be required to operate flexibly to respond to these changes.

Flexible carbon capture has been studied for amine absorption,[1-2] a leading CCS technology. This work explores the possibility of flexible carbon capture using membrane separation, a promising alternative to amine absorption. In particular, membranes are considered to be very responsive to system changes and require very short start-up times.[3] In addition, membrane separation has advantages such as having a smaller footprint, being more environmentally benign (no corrosive chemicals involved in the separation process), and potentially incurring lower separation energy.

In this work, we perform optimization to determine the optimal process design and time-varying operations of a polymeric membrane system separating CO_2 from a natural gas combined cycle (NGCC) with wind energy integration. The total net present value (NPV) of the gas turbines and membrane system is maximized. Both design and operations of the capture plant are optimized. Design decision variables include membrane process configuration, membrane size, CO_2/N_2 selectivity and CO_2 permeance (two key membrane properties relevant to separation performance), and compressor and vacuum pump sizes. These parameters are determined before a capture unit is built. After the plant is built, operational decision variables include gas flowrates, the pressure ratio across the membrane and permeate-side (low-pressure side) pressure. These are parameters that can be adjusted, within limits, given electricity market conditions for a given time period.

Time-varying electricity output from gas turbines as well as the associated flue gas flowrate and composition will be determined by HyPPO, an in-house software developed at Stanford University for modeling and optimization of flexible and renewable-integrated power systems. HyPPO models beneficial operating strategies for a set of statistically representative days. HyPPO results will be used with membrane separation models for various process configurations as modeled in MATLAB.

1. Cohen, S. M.; Rochelle, G. T.; Webber, M. E., Optimizing post-combustion CO_2 capture in response to volatile electricity prices. *International Journal of Greenhouse Gas Control* **2012,** *8*, 180–195.
2. Mac Dowell, N.; Shah, N., The multi-period optimisation of an amine-based CO_2 capture process integrated with a super-critical coal-fired power station for flexible operation. *Computers & Chemical Engineering* **2015,** *74*, 169–183.
3. Brunetti, A.; Scura, F.; Barbieri, G.; Drioli, E., Membrane technologies for CO_2 separation. *Journal of Membrane Science* **2010,** *359* (1), 115–125.