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Simultaneous CAPEX and OPEX optimization of a carbon capture plant: Combined-Cycle Gas Turbine case study

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Abstract

Amine based process is the state-of-the-art for post-combustion carbon capture. The process operates in a thermal swing closed loop mode where the solvent is regenerated using thermal energy, usually supplied by low pressure steam. The steam supplies the energy requirements of the reboiler which typically ranges from 2.5 to 3.6 MJ/kgCO_2. The reboiler energy requirement is dependent on the solvent type, process operating conditions and flue gas composition.

For many years, research was focused on developing new solvents that would reduce the regeneration energy requirement. Solvents like CESAR1 (a blend of Aminomethyl propanol and piperazine) significantly reduced the energy required to regenerate the solvent compared to monoethnolamine (MEA). The energy requirements of most commercial/proprietary solvents are in the same order as that of CESAR1[1].

However, it is essential to note that the energy requirement impacts only the operating costs (OPEX) of the capture plant. The capital costs (CAPEX) are influenced by other factors. Usually, there is a trade-off between CAPEX and OPEX. For instance, the CESAR1 solvent is less energy intensive than MEA, reducing the amount of steam required for its regeneration. However, it reacts slower with CO_2, thus requiring a taller absorber tower (increasing CAPEX). To properly evaluate the impact on the total cost of a capture plant, an optimization including both the plant design and operating parameters is required. Typically, the process of designing a the carbon capture plant starts by focusing on energy optimization followed by a cost estimation on a select few cases.

Implementing an optimization routine to estimate CAPEX/OPEX is usually not practical due to significant increase in simulation convergence complexity and the associated computational time. The new 9.0 version of ProTreat® is featured with a new thermodynamic model for CESAR1 which is able to predict capture rates with less than 2% deviation[2,3]. Moreover, it's new case study feature allows for a systematic review of the equipment costs and energy

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requirements thereby allowing a simultaneous optimization of both CAPEX and OPEX.

A case study involving a generic combined cycle gas turbine power plant[4] (about 400 MW net power) is performed and used to demonstrate the methodology of estimating the total cost of a capture plant. The plant was modelled in ProTreat®. In this case, the steam from the low-pressure turbine was extracted to provide the energy for the solvent regeneration (See Figure 1).

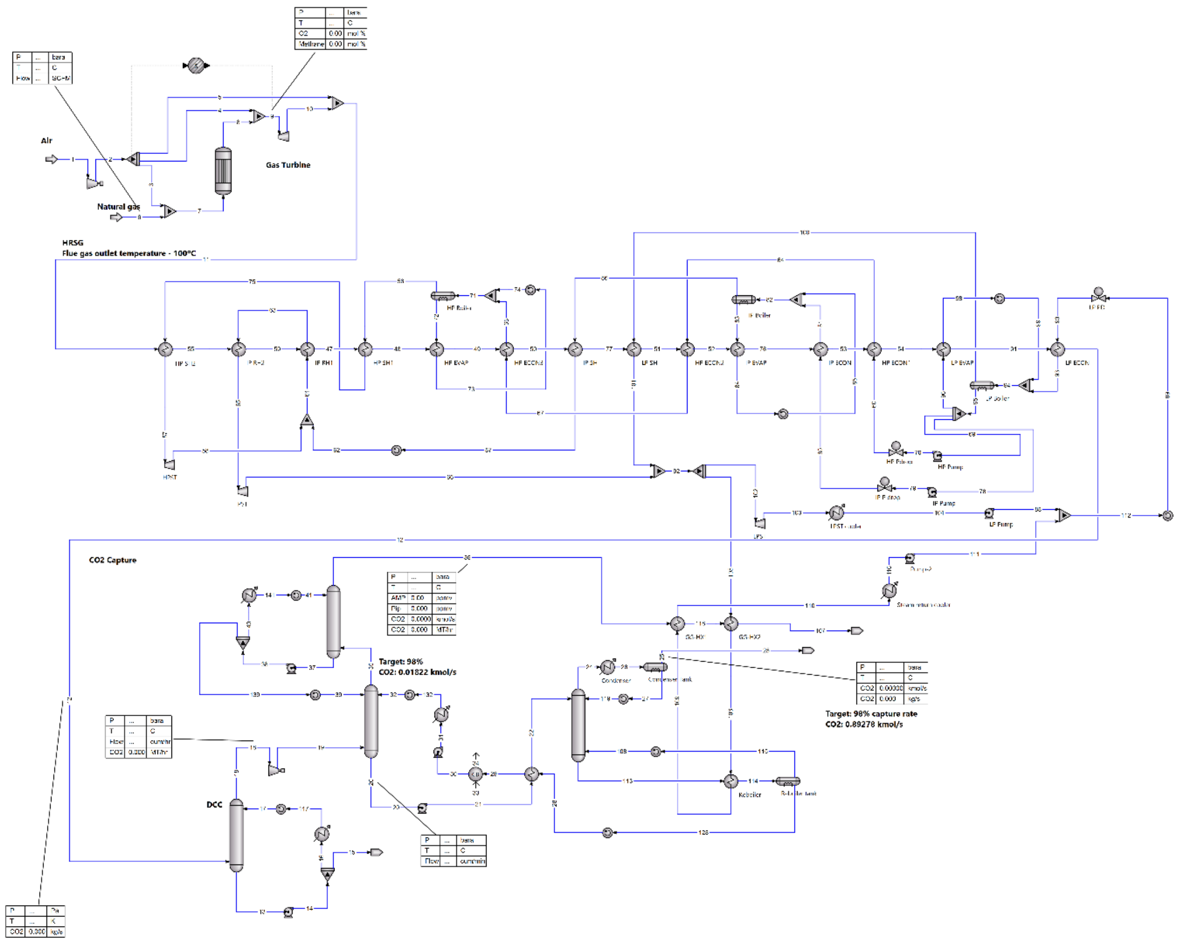

Figure 1: Combined cycle gas turbine power plant with carbon capture modelled in ProTreat.

The process was evaluated for different configurations such as columns (absorber and stripper) packing heights, presence and placement of intercoolers, solvent circulation rates, etc. For each step, the novel case study calculated the cost of the equipment and total cost of the capture plant was assessed.

An example of the process optimization is shown in Figure 2. With the new case study feature, it is possible to evaluate the process cost for each point of the SRD curve, allowing for a higher granularity in the cost assessment. By evaluating the impact of CAPEX and OPEX simultaneously, this study allows for a better understanding of the design and economic feasibility of the carbon capture process. For the capital cost estimation, the methodology described in Turton et al. (2018)[5] is used.

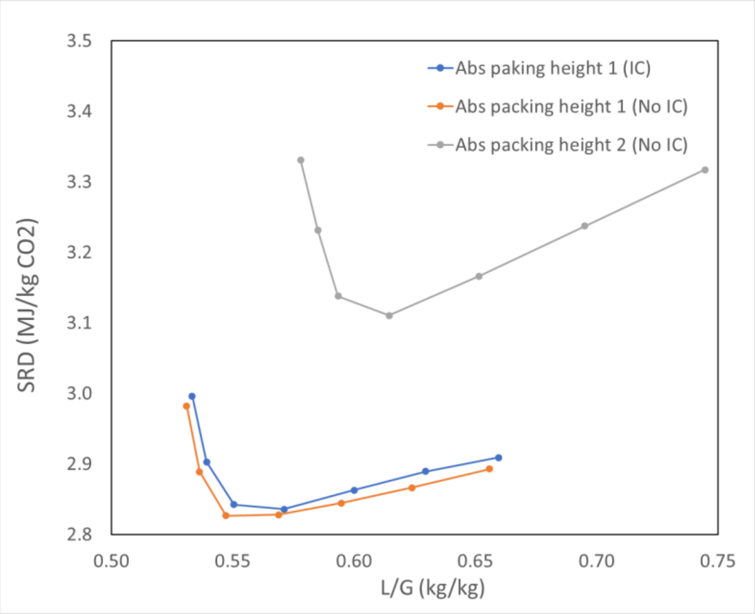

Figure 2: Specific Reboiler Duty optimization.

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