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Power / cost trade-offs associated with solvent based PCC

Trent Harkin[a,b]*, Andrew Hoadley[a,b], Barry Hooper[a]

[a]*Cooperative Research Centre for Greenhouse Gas Technologies, University of Melbourne, Parkville, Vic 3010, Australia*
bDepartment of Chemical Engineering, Monash University,Clayton, Vic 3800, Australia

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1. Introduction

The addition of carbon capture and storage using solvent based absorption to a power station will reduce the net power generated from the power station due to the heat and power required to separate and compress the CO_2. The cost of electricity (COE) produced from the power station will also increase due to the added capital and operating expenses incurred by the CO_2 capture and storage. The design of the carbon capture plant is important to help to minimise the energy penalty and the increase in COE due to the addition of CCS. When designing a power station changes can be made which have opposing impacts on the performance of the power station and optimising the process can be difficult. A method that combines simulation, heat integration and multi-objective optimisation (MOO) will be presented which can be used to aid in the design of a CCS plant. The method is applied to a typical brown coal fired power station in Victoria using a potassium carbonate solvent.

2. Method

The method developed to design power stations with CCS plants involves an automated combination of simulation, automated heat integration using linear programming and MOO as arranged in Figure 1. The power station and carbon capture plant are modelled using Aspen Plus®, heat curves are automatically extracted from the model into an Excel based heat integration program. The program then uses the heat curves to generate a Grand Composite Curve, which can be used to determine the maximum amount of power that can be generated for a given steam cycle.

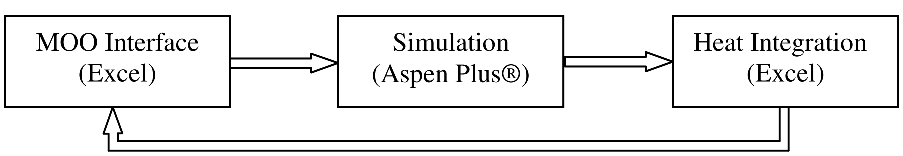

Figure 1: Optimisation approach for power stations with CCS

The simulation and heat integration program can be used to estimate capital and operating costs for the CCS infrastructure. The results are then analysed using an Excel base MOO program using NSGAII code to determine optimal solutions to the optimisation problem.

3. Case Study - Description

The case study is based on a typical 500 MWe power station in Victoria. Victoria has low fuel costs and so the existing power stations have been designed with low capital cost / low efficiencies to minimise the COE. Low levels of sulphur in the coal found in this region also mean that the power stations do not require desulphurisation equipment. Advantages of potassium carbonate for CO_2 capture from power stations over more commonly used amine based solvents include low volatility, lower cost, lower rates of degradation and the ability to absorb the incoming SOx and NOx compounds and form potentially useful potassium sulphates/nitrates avoiding the need for additional equipment for removal of the SOx and NOx. This case study uses the traditional 30 wt% potassium carbonate process and therefore this process will generally require more regeneration energy than amine based solvents. A typical potassium carbonate process added to the power station, without any thoughts of heat integration will reduce the net power to 310 MWe, an energy penalty of 38 %. Two optimisation problems have been reviewed where each problem has two objectives;

Opt. 1. Maximise the CO_2 capture rate and maximise the net power generation.

Opt. 2. Maximise the CO_2 capture rate and minimise the ΔCOE.

In each of the optimisation problems the variables that can be manipulated includes the solvent lean loading, flowrate and temperature, regenerator pressure, absorber and regenerator feed gas temperature and the ΔT_{min} of the heat exchanger network.

4. Case Study – Results

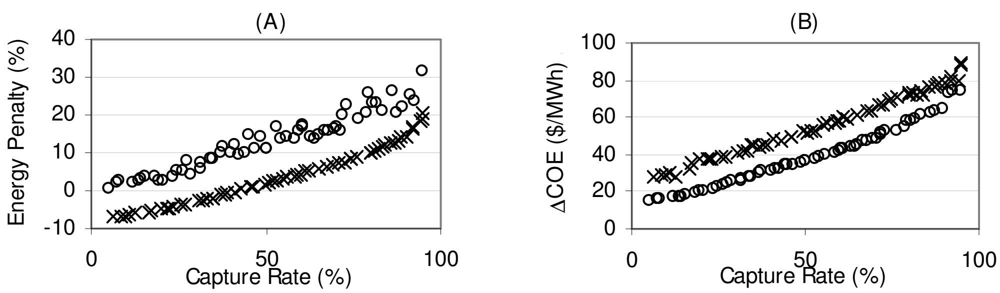

Figure 2: (A) Energy penalty and (B) ΔCOE for the optimised solutions for Opt. 1(×) & Opt. 2(○).

The first optimisation problem reduces the energy penalty for a CO_2 capture rate of 90 % capture to 16 %. The first optimisation problem also suggests that up to 40 % capture can be achieved without any loss of power due to the current inefficiencies in the power station (refer to Figure 2A). The second optimisation problem that suggests, even though the energy penalty can be lower, that to minimise the ΔCOE the energy penalty should be about 25 % (90 % CO_2 capture) which is greater than the minimum energy penalty, but well below energy penalty without regard to heat integration. Figure 2B shows that even though the energy penalty for all solutions in the second problem are greater than the first problem, the ΔCOE is lower. This is due to the high capital costs required for the heat exchanger network required to meet the minimum energy penalty and this further emphasises the economics in Victoria which favour power stations with low capital cost rather than high efficiency power stations. Optimisation has shown that the net power from a 500 MWe power station retrofitted with CCS can be as high as 420 MWe, however in the Victorian context the optimum net power is going to be closer to 375 MWe, still much higher than the un-optimised design output of 310 MWe.

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