1st Post Combustion Capture Conference

Effect of varying electricity and carbon prices on operation and capture levels in flexible post-combustion CCS power plants

Olivia Errey*, Mathieu Lucquiaud, Hannah Chalmers and Jon Gibbins

The University of Edinburgh, School of Engineering, King's Buildings, Edinburgh, EH9 3JY, UK

Post-combustion capture; Flexible operation; Optimisation

1. Introduction

Amine based post combustion capture technologies were originally developed to operate in process industries at base-load steady state operation. To transpose these technologies into integrated power cycles, different objectives exist; the generation of power with low carbon emissions, while responding to meet the specific requirements of rapidly varying electricity and carbon markets. This responsiveness requires process design which enables flexible operation of power output and CO_2 capture rates. Previous work has primarily explored flexibility through capture plant bypassing and solvent storage. This paper builds on this work to explore optimum CO_2 capture levels for power plants using an aqueous solvent capture system based on 30%wt MEA. The modeling approach combines the power cycle, the amine capture unit and the compression train. Outputs from the simulation are used as the basis for an assessment of how plants might be operated to maximize revenue under varying electricity and carbon price scenarios.

2. Modelling approach and result trends

The integrated CCS power plant model used has been developed to evaluate the ratio between the heat supplied for solvent regeneration and the loss of generator output, defined as the coefficient of performance of steam extraction COPx at high removal rates. As will be discussed, COPx varies with steam extraction rate, the ratio of the mass flow of steam entering the solvent reboiler to the mass flow of steam entering the low pressure turbine before capture is added. Higher steam extraction rates result in a reduction of the IP/LP crossover below its design value despite the addition of a control valve.

The solvent temperature in the reboiler is strongly affected by the temperature pinch between condensing steam and boiling solvent. Heat transfer is mostly driven here by conduction and the pinch varies linearly with the steam and the solvent flow rates. At high steam flow rate the increased temperature pinch leads to a reduction of solvent regeneration temperature, which is detrimental to the energy of regeneration since lower reboiler temperature

* Corresponding author. Tel.: +44-(0)131-6507449;
E-mail address: o.errey@ed.ac.uk

reduces the ratio of CO_2 to steam in the stripping gas. When extracted steam flows are below the reboiler design value it is necessary to throttle the reboiler extraction line slightly in order to maintain the appropriate solvent regeneration temperature and avoid overheating the solvent.

The overall electricity output penalty of capture (EOP) in kWh/tCO_2, defined as the sum of the respective contribution of steam extraction, CO_2 compression and ancillary power, is examined for a range of solvent lean loadings and for varied absorber packing heights. At higher capture levels two phenomena are taking place. Solvent capacity needs to be increased to capture the additional amount of CO_2 by increasing solvent flow rate, hence increasing in the EOP associated with solvent circulating pumps. Higher amount of stripping are also necessary to reduce solvent lean loading, increase the driving force for mass transfer at the top of the column and thus reduce the partial pressure of CO_2 in the flue gas leaving the absorber. This *de facto* increases the contribution of solvent sensible heat to solvent energy of regeneration, and the solvent energy of regeneration. Consequently, the optimum overall EOP occurs at lower solvent lean loading. It should be noted this has the effect of reducing the partial pressure of CO_2 in the stripper, and increase the EOP associated with CO_2 compression.

Overall, the EOP tends gradually to increase with capture level until an intrinsic operating limit for a particular absorber configuration is reached. This limit is effectively a mass-transfer limit rather than a thermodynamic limit, with the absorber packing not having the capacity to remove the amount of CO_2 required when the driving force at the top of the column in insufficiently low to achieve the CO_2 partial pressure required. Solvent flow rate, and hence the overall EOP, has then to drastically increase.

Converting the EOP into a loss of potential revenue, through assumed electricity prices, and balancing this against cost for emitted CO_2 as the operating capture level suggest that operating revenues from CCS power plants can sometimes be improved by operating a post-combustion capture unit beyond its design capture level (e.g. 90% - a value assumed in many studies), or at lower levels or even not at all. This need to follow ‘real-market’ operating conditions obviously would have wider consequences on the design of other components of the CCS chain, e.g. on pipeline capacity. If pipeline capacity is going to increase to allow plant operation close to optimum levels, the additional capital cost implications of designing for a higher maximum flow rate needs to be understood, although this is beyond the immediate scope of this analysis.