1st Post Combustion Capture Conference

"CCGT with CCS - integration options"

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With emissions levels for new built CCGT plants without carbon capture at around 350 kgCO_2/MWh, it is expected that they will not be able to operate without CCS beyond 2030. In order to avoid the deployment of 'unabated' gas-fired plants, requirements to fit CCS not only to coal but to gas-fired plants need to be adopted to prevent any inconsistency. Once built, it would be very costly or even infeasible to retrofit the new facilities with CCS, thus "locking-in" many years of CO_2 emissions.

Currently in the UK there are no new unabated coal plants under construction, whilst around 4.7 GW of new gas plants are expected to come online over the next few years [1]. As in the UK there are a significant number of CCGT power stations recently permitted or waiting to be granted consent they have been required to be CCR so that CCS can be retrofitted once it is commercially viable. It is therefore of a paramount importance to understand what are the feasible options/issues when CO_2 capture is applied to the CCGT units.

This paper is focusing on capture consideration based on post-combustion technology for gas fired plants. When a CCGT plant is designed to be ready for retrofit one of the most important technical consideration is the steam extraction pressure and flow to provide the energy necessary for solvent regeneration as this will have a large impact on the overall plant efficiency. Available options for steam and electricity supply to meet the requirements of the CCS process have been assessed. Also issues related to capture plant footprint are considered. The findings of this paper are relevant to project developers and power generators who have an interest in the potential for CCS to provide an emissions abatement option for the new CCGT assets in the long term.

"Keywords: CCS, CCGT, integration"

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1. Introduction

On 25 June 2009, the EU Directive 2009/31/EC relating to the geological storage of carbon dioxide entered into force. The Directive forms part of the EU's Climate Change Package, developed in the context of the need to achieve the GHG emission reductions targets. Preliminary estimates indicate that up to 160 million tonnes of CO2 could be stored by 2030, accounting for some 15% of the EU's required reductions. It should be noted that the Directive does not make CCS mandatory but establishes a legal framework for the environmentally safe geological storage of CO2 upon which CCS deployment could move forward.

In the UK, the Committee of Climate Change (CCC) concluded that in order to meet the 80% emission reduction target set for 2050, the power sector would need to be largely decarbonised by 2030 [2]. As the emission reduction required by 2030 is substantial, it is likely to require contributions from renewable, nuclear and CCS. By 2030, any plant running for extended periods will probably have to be able to achieve annual average emissions levels of

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100gCO_2/kWh or below vs. the present level of 560gCO_2/kWh. In this context, the new regulations by Department of Energy and Climate Change (DECC) for making power plants CO_2 capture ready apply to all combustion plants at or above 300MW output in the UK [3].

2. Challenges for CCS retrofit to CCGT power plants

The current technical challenges of the post-combustion (amine based) technology for natural gas-fired CCGTs are as follows:

- Lower concentration of CO_2 means that mass transfer is more difficult for CO_2 capture from gas fired flue gas. This results in large absorbers and significant land footprint issues. With a typical flue gas CO_2 concentration of 3-4%, much larger volumes of flue gases must be processed for the same quantity of CO_2 when compared with coal fired plants (i.e. flue gas CO_2 concentration 13-14%) necessitating as a result higher solvent consumption/t CO_2 captured;
- As O_2 concentration in flue gas is also higher than in coal fired plants, this could be an additional issue for the solvent if not managed properly - continuous replacement of solvent being a significant operating cost;
- Large gas-gas heat exchangers might be required in order to mitigate the plume formation;
- The power plant might need to be equipped with Selective Catalytic Reduction (SCR) to reduce NOx concentration in the flue gas in order to reduce amine waste; and
- The need for a reliable steam supply for amine regeneration in the reboiler.

2.1. CCGT with CCS – Heat Integration Options

The most energy intensive aspects of solvent-based post-combustion CO_2 capture processes are the supply of heat for solvent regeneration and shaft power for CO_2 compression. Auxiliary power demand for the capture plant is equivalent to 10-20% of the plant gross power output and corresponds to the anticipated energy requirements for the on-site carbon capture facilities. Heat demand equivalent to 30-50% of the steam flow through the steam turbine is required by the capture process using standard MEA solution, at dry saturated conditions and 3-4 bar(a) pressure.

Those figures are conservative and could be reduced once the capture technology has been improved, notably via the use of higher performance solvents.

As the gas turbine will not be modified and continue to operate under designed conditions when capture is retrofit, carbon capture ready considerations for the plant have to be included at design stage.

Heat can be supplied using low pressure (LP) steam extracted from the steam turbine's intermediate pressure/low pressure (IP/LP) crossover pipe. This arrangement significantly reduces the power plant's net electrical efficiency hence net power output. However, gains in efficiency can be made through adequate thermodynamic integration between the steam cycle and the carbon capture plant if considered early on during the design stage of a new build power plant. There are three main options for steam supply for the amine regeneration process as follows:

1. Steam is taken from the CCGT plant by integrating main plant steam and feed water cycle with the carbon capture plant (CCP);
2. Steam is generated from auxiliary boilers; and
3. Steam and electricity are generated by and dedicated combined heat plant (CHP).

A number of options for capture ready steam turbines when steam is provided from the main plant have been proposed .

In this paper, we have focused our attention on different options of providing steam to the capture process from the main plant and for comparison have also considered the efficiency penalty introduced by using auxiliary boilers.

A separate CHP plant could simultaneously supplies the required steam and electricity at an up to 80% overall thermal efficiency. The CHP plant would have to be designed to satisfy both the electricity and steam demands of the carbon capture plant. Typically a CHP scheme aims at maximising the power generation for a given heat load in order to maximize its thermal efficiency and favour economy of scale for costs, both capital and operational. Depending on the capture plant requirements surplus electrical power for the required heat load might be produced which could lead to transmission export capacity to be exceeded. This would be a major undertaking, itself facing numerous potential barriers, including environmental permitting, land availability, fuel supply and transmission export capacity.

Overall, each option would require significant capital costs. Therefore, a detailed techno-economic study would have to be carried out to evaluate the technical and financial performance of various options over the operational lifetime of the carbon capture plant. Key performance indicators such as net present value (NPV) and levelised costs of generation would be derived to identify the preferred option.

Addition of capture plant to a CCGT plant is typically estimated to incur an efficiency penalty of around 7% points, LHV depending on the steam extraction place.

Using auxiliary boilers would require minimal changes to be made to the CCGT plant upon the installation of CCP equipment since steam for the CCP is generated separately and not extracted from the main plant. Additional flue gas from the auxiliary boilers will be routed to the same CCP for the CCGT plant. The additional CO_2 in the flue gas would impose a requirement for larger CCP equipment.

2.2. CCGT with CCS – Plant footprint

An important broader point that we feel is currently inadequately reflected in the CCR guidance is that any layout is site specific and any footprint reference assumes a set of retrofit equipment, applicable to the scenario, and a differing layout would be required depending on:

- Availability of cooling water (e.g. seawater cooling vs. air-cooling);
- Additional flue gas pre-treatment required before CO_2 capture;
- Type and extent of CO_2 transport conditioning (e.g. for shipping or pipeline, to what pressure conditions);
- Column sizing (diameter, height, cross-sectional profile) for absorber and stripper
- Use of dedicated auxiliary power and steam supply (e.g. CHP plant) for the Capture Plant, rather than full integration
- Potential need for new utility supply equipment (CW, DW, compressed air etc) and stacks
- Amine storage capacity (for peaking operation, accumulate lean amine in off-peak hours?)

In addition, a significant plot space is required for construction, aspect very important with respect to the overall construction cost and time schedule.

The layout also depends to some degree on how much land is available. Plants can often be squeezed into smaller areas if necessary but at a cost, so the regulator should be able to permit plants with smaller areas if the developer can provide evidence that they could build a capture plant in that area and they would be willing to accept any cost penalties.

3. Conclusion

As the level of integration between the existing power plant and the capture plant is likely to be very challenging if not impossible mainly due to the space constrains, options for supplying the steam and power to the CCS plant from independent sources were investigated in the paper.

There is a low risk of impairing power generation reliability – flue gas treatment can simply be disconnected if CCP unit is out of operation and the CCGT main stack can be used during the CCP bypass operation.

It is expected that CCS technologies would improve following demonstration projects and technology development which would lead to lower steam and power consumption, smaller equipment footprint and ultimately lower capital costs.

4. References

[1] Department of Energy and Climate Change, 2009. Applications Under Consideration. Recent Decisions on Applications. https://www.og.decc.gov.uk/EIP/pages/applications.htm

[2] Committee on Climate Change, 2009. Meeting Carbon Budgets – the need for a step change, Progress report to Parliament.

[3] Department of Energy and Climate Change, 2009. Carbon Capture Readiness (CCR). A guidance note for Section 36 Electricity Act 1989 consent applications, URN 09D/810, November 2009.