CONCERT Project - CarbON CapturE Ready gas Turbine

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Introduction

The large adoption of renewable energies is crucial to meet the long-term objective of CO_2 neutrality by 2100. But, according to the International Energy Agency (IEA), the current growth of renewable energy is not large enough to replace our consumption of fossil fuels in the same period [1]. In addition, with the growing share of intermittent power from solar and wind in the electricity mix, there is a rising interest and demand of these flexible power production units from non-renewable sources. With flexible we refer to power production units that can quickly shift between part and full load maintaining high efficiency.

Micro gas turbine (mGT) units running on natural gas offer such flexibility. Nevertheless, a problem is the low CO_2 concentration in the exhaust gas. Although this concentration is low, due the low carbon content of natural gas and the high air to fuel ratio, it is disadvantageous from a Carbon Capture (CC) point of view. In fact, considering a Monoethanolamine-based (MEA) chemical absorption which is one of the most mature post-combustion CC technologies, the low CO_2 concentration increases the capital cost and the energy penalty of the plant. A possible solution is performing Exhaust Gas Recirculation (EGR) on micro gas turbine to increase the CO_2 content in the stack and to reduce the mass flow rate of the flue gas,in order to reduce the capital cost of the capture plant and the thermal energy needed to regenerate the solvent and extract the CO2.

Methodology

The numerical models of the mGT and the CC plant are both realized in Aspen Plus®[2]. The mGT model has already been modelled and validated against experimental data. The experimental results were obtained from measured data on the Turbec T100 installed at the labs of the VUB. The mGT was operated under constant power conditions. A description of the test rig and the used measurement equipment can be found in [3]. The EGR stream is simulated in Aspen Plus®by splitting part of the exhaust gases, cooling the gases down, separating the condensed water and finally installing a blower to provide the necessary pressure increase for EGR. The plant is presented schematically in Figure 1.

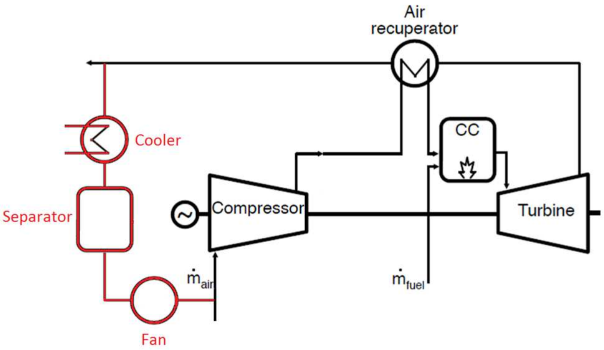

Figure 1: Synthetic representation of the EGR channel coupled to the mGT Turbec T100

As for the CC plant, we refer to the Pilot-scale Advanced Capture Technology (PACT) facilities at the UK Carbon Capture and Storage Research Centre (UKCCSRC) [4]. The considered experimental data set can be found in [5].

The Rate-Based MEA model is adopted and it provides a rate-based rigorous simulation of the process. Key features of this rigorous simulation include electrolyte thermodynamics and solution chemistry, reaction kinetics for the liquid phase reactions, rigorous transport property modelling and rate-based multi-stage simulation with Aspen Rate-Based Distillation. In open literature, this thermodynamic model for CO_2 absorption in aqueous MEA solution is extensively validated against the set of experimental data [6, 7]. The main components of this CC plant are the absorber, strip-

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Table 1: Comparison between Akram experimental data, Akram numerical model and the current numerical model

Model inputs		Akram experimental data [5]	Akram model [5]	Current model
CO_2 in flue gas	[vol %]	8.3	8.3	8.3
Solvent flow	[kg/h]	604	604	604
Mass flow rate of flue gas	[kg/h]	247.9	247.9	247.9
Liquid to Gas ratio (L/G)	-	2.4	2.4	2.4
Flue gas temperature	[°C]	38	38	38
Lean solvent temperature	[°C]	40	40	40
Cold approach temperature	[°C]	18.5	18.5	18.5
Hot approach temperature	[°C]	19.84	19.8	19.8
Lean solvent concentration	[wt %]	29.8	29.9	29.9
Lean Loading	[molCO_2/molMEA]	0.18	0.181	0.181
Results				
Rich solvent concentration	[wt %]	27.5	28.9	29
Rich Loading	[molCO_2/molMEA]	0.417	0.410	0.410
Specific Reboiler Duty	[MJ/kgCO_2]	6.1	5.9	6
Stripper bottom temperature	[°C]	108.8	108.8	107

per, pumps and heat exchangers. The flue gas from the power plant enters the absorber where CO_2 is extracted from the flue gas, and then the treated gases go out from the top of the absorber. The rich solution with CO_2 is pumped into the stripper to separate the CO_2 from the solution. The outgoing CO2 stream will be pressurized, while the lean solution without CO_2 will go back to the absorber to form a cycle. Besides, there is a heat exchanger between the rich solution and lean solution to recovery the heat.

The comparison between experimental results and simulation results from Akram's paper and the current model results for the CO2 capture plant is given in Table 1. As may be seen, the current model results are in good agreement with the Akram's results.

In a next stage of our project, the CC model will be coupled with the mGT with EGR model, taking into consideration that the concentration of CO_2 and the mass flow rate of the flue gases after applying the EGR loop are different from the case studies analysed by Akram. For this reason, the absorbing and the stripping columns must be replaced with optimized ones in order to maintain the hydraulic behaviour inside the columns unvaried, but always keeping the same physical models.

Conclusions

The objective of this paper is to identify the influence of the CC plant on the mGT plant due to electric and thermal energy demand it has, which can be expressed in terms of thermal and electric efficiency variation of the whole plant. With this in mind, a detailed analysis of the energy fluxes will be carried out in order to optimize the entire system from an energy-integrated point of view.

This research will gain fundamental thermodynamic insight in combining EGR with a mGT and it will introduce a new type of thermodynamic cycle, which combines high efficiency and flexibility with low carbon emissions. This is very important for current and future power production. In fact, with effects of global warming becoming more and more visible, this combination will gain interest in the near future.

Acknowledgments

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