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Process evaluation of an 865 MW_e lignite fired O_2/CO_2 power plant

Klas Andersson *, Filip Johnsson

Department of Energy and Environment, Energy Technology, Chalmers University of Technology, SE-412 96 Göteborg, Sweden

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Abstract

In order to reduce emissions of carbon dioxide from large point sources, new technologies can be used in capture plants for combustion of fossil fuel for subsequent capture and storage of CO_2. One such technology is the O_2/CO_2 combustion process (also termed oxy-fuel combustion) that combines a conventional combustion process with a cryogenic air separation process so that the fuel is burned in oxygen and recycled flue gas, yielding a high concentration of CO_2 in the flue gas, which reduces the cost for its capture. In this work, the O_2/CO_2 process is applied using commercial data from an 865 MW_e lignite fired reference power plant and large air separation units (ASU). A detailed design of the flue gas treatment pass, integrated in the overall process layout, is proposed. The essential components and energy streams of the two processes have been investigated in order to evaluate the possibilities for process integration and to determine the net efficiency of the capture plant. The electricity generation cost and the associated avoidance cost for the capture plant have been determined and compared to the reference plant with investment costs obtained directly from industry. Although an existing reference power plant forms the basis of the work, the study is directed towards a new state of the art lignite fired O_2/CO_2 power plant. The boiler power of the O_2/CO_2 plant has been increased to keep the net output of the capture and the reference plant similar. With the integration possibilities identified, the net efficiency becomes 33.5%, which should be compared to 42.6% in the reference plant. With a lignite price of 5.2 $/MWh and an interest rate of 10%, the electricity generation cost increases from 42.1 to 64.3 $/MWh, which corresponds to a CO_2 avoidance cost of 26 $/ton CO_2.

Keywords: O_2/CO_2 recycle combustion; Oxy-fuel; Process layout; Cost analysis

1. Introduction

Capture and storage of CO_2 has the potential to contribute to a significant and relatively quick reduction in CO_2 emissions from power generation, allowing fossil fuels to be used as a bridge to a non-fossil future and taking advantage of the existing power plant infrastructure. Commonly studied processes in the literature for

* Corresponding author. Tel.: +46 31 7725242; fax: +46 31 7723592.
E-mail address: Klas.Andersson@me.chalmers.se (K. Andersson).

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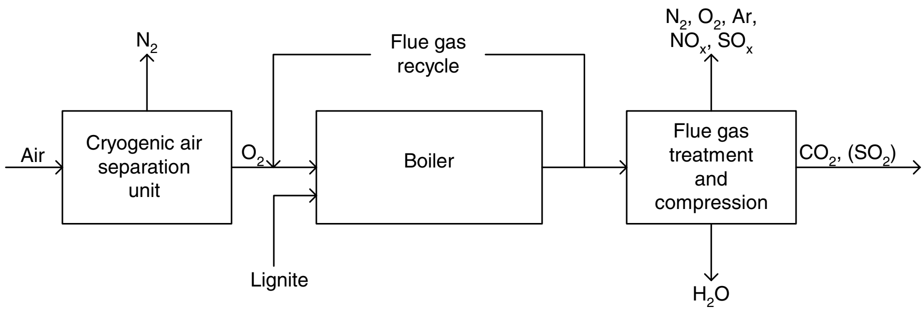

Fig. 1. Principal outline of the O_2/CO_2 process.

the purpose of CO_2 capture from coal fired power plants are the amine based absorption processes, the integrated gasification combined cycle (IGCC) and the O_2/CO_2 combustion process (or oxy-fuel combustion). Plant economics and performance have been evaluated in a number of studies, e.g. [1–6], where the avoidance cost of the captured CO_2 is normally used for comparing the costs of the various schemes. This work presents the costs for CO_2 capture using the O_2/CO_2 combustion process, which is applicable to different types of fuels and boilers. O_2/CO_2 combustion involves burning the fuel in an atmosphere of oxygen and recycled flue gas instead of in air, as schematically outlined in Fig. 1. The mixed flow of oxygen and recycled flue gas is fed to the boiler together with the fuel, which is burned as in a conventional plant. Typically, 70–80% of the flue gas is recycled from downstream of the economizer and mixed with the oxygen. The remaining part of the flue gas is cleaned, compressed and later transported to storage or to another application. Studies on O_2/CO_2 combustion have mainly concerned emissions and combustion behaviour (e.g. [7,8]) together with overall process studies (e.g. [6,1]). This work combines a comprehensive study of flue gas treatment together with the integration possibilities of the O_2/CO_2 process, resulting in a proposal for an overall process layout. Commercial process data are applied in order to identify the possible problems of the components in the process and to obtain design requirements under conditions that are as real as possible. Both absorption based capture processes (e.g. MEA absorption) and O_2/CO_2 combustion are often considered as alternatives for retro-fitting existing coal fired units [1,2], making it possible to take advantage of the already invested capital, which, to a certain extent, can be considered as sunk costs. However, existing units are often old units with rather modest net efficiencies, and with the increased parasitic losses of the capture, the retro-fit concept results in comparatively high fuel costs. It should, therefore, be pointed out that although an existing reference power plant has been the basis of the process design of this study, the present work should be considered as a feasibility study for a new O_2/CO_2 fired power plant, including costs, process integration and optimization of the steam cycle, ASU (air separation unit) and flue gas treatment pass and applying commercial state of the art process and costs data as the basis. Furthermore, as a comparison, the associated costs are determined for a capture plant both with and without an SO_2 removal system (wet flue gas desulphurization (FGD)) in order to show the possible economic benefit from combined capture of SO_2 and CO_2, i.e. in case this will be environmentally approved and applicable to the type of storage considered.

2. Method

The 2×865 MW lignite fired Lippendorf power plant is used as the reference in this study. This is a modern state of the art power plant that was commissioned in the year 2000. Table 1 lists the main process data of the plant. In [9], more detailed information is available on the process integration part of the study. Further details are also given in [10,11]. Since the focus in the previous work was rather on the performance and design of the O_2/CO_2 process, the plant was derated compared to the reference plant due to the increased internal electricity demand of the equipment added, i.e. mainly the ASU and the CO_2 compressors. Since the aim of this study is to illustrate the environmental implications and costs associated with a new O_2/CO_2 power plant, the net electricity output is kept the same as in the reference plant. This results in an increased boiler power of the capture plant, which is obtained by multiplying the reference boiler power with a simple scaling factor: