EVALUATION OF OXYFUEL TECHNOLOGY AS CO_2 CAPTURE OPTION IN COAL COMBUSTION

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EXTENDED ABSTRACT

The aim of this paper is to assess one of the possible technological options of CO_2 capture through the technology of oxy-combustion in order to reduce the carbon dioxide emissions,that is the main greenhouse gas that contributes to increase the global warming. Particularly, we focused this issue in the case of Spain, where is being developed a project which consists in the construction of a test facility for advanced technologies for CO_2 capture in coal power generation.
The general design criteria of El Bierzo Test Facility has the following main characteristics: modularity: layout as independent but interconnected modules (combustion, oxy-combustion, flue gas treatment…) allowing simultaneous or separate operation for independent study of processes; flexibility: possibility of operation under a wide range of operating conditions, including different coals and combustions from air mode to oxymode; integration: designed to study full process integration of the different units and systems; efficiency: conceived giving great importance to heat integration and performance optimisation without putting into compromise requirements for flexible testing.Extension: layout allowing for extensions at a later stage in line with any technological progress and/or strategic development; safety: risk analysis assessment (hazop methodology) to be performed to improve safety and operability of the process and safety instrumented systems (sis) will fulfil requirements of functional safety standards; monitoring: comprehensive and advanced in-furnace monitoring of the combustion and CO_2 capture processes. Concerning to the design criteria the conclusion is that, in particular, the modularity, flexibility, monitoring and control capabilities and the planned lay-out, allowing for extensions at a later stage in line with any technological progress and/or strategic developments is well taken care of.
As regards to the plant configuration, we can conclude that the installation offers the possibility of operating under a wide range of selected operating conditions, particularly in different degrees of oxicombustion (from air to pure oxygen), allowing for the simulation of different scenarios of the operation of pulverized coal power stations. This would offer the possibility to obtain useful results and conclusions towards the potential application on utility scale.

Keywords: CO_2 capture, oxyfuel, coal, combustion

1. INTRODUCTION

The aim of this paper is to evaluate one of the possible technological options of CO_2 capture through the technology of oxy-combustion in order to reduce the carbon dioxide emissions, which is the main greenhouse gas that contributes to the global warming.

It is well known that carbon dioxide capture and storage (CCS) is a critical technology to significantly reduce CO_2 emissions. CCS in power generation, industry and fuel transformation could account for 20% of CO_2 savings (6.5 Gt of CO_2 captured and stored annually in 2050).[1]

Particularly, we focused this issue in the case of Spain, where is being developed a project which consists in the construction of a Test Facility for advanced technologies for CO_2 capture in coal power generationThe oxy-combustion is a combustion process with a hydrocarbon fuel, with oxidation using a high purity oxygen stream. Furthermore, the fuel is burned with oxygen instead of air, producing a flue stream of CO_2 and water vapour without nitrogen. From this stream the CO_2 is relatively easily removed. The oxygen required for the combustion is extracted *in situ*, from air.[2] The main characteristics of the process are:

- Products of combustion are essentially H_2O and CO_2.
- Oxidizer is, ideally, pure oxygen.
- Temperature control at the burner nozzle and in the combustion zone is achieved by a combination of steam (water injection) and optimized thermal extraction.

The early interest (pre-1980's) in this technology was focused on producing a high purity CO_2 gas stream that could be used for the process known as enhanced oil recovery (EOR), consisting in the CO_2 injection, mainly into declining US oil fields.
Today the focus is on energy production while minimizing CO_2 emissions.There are several projects around the world that aims to demonstrate this technology, including large scale pilot and demo projects. Among them, there's one that is being developed in Spain, the "Test Facility for CO_2 Capture Technologies El Bierzo", an initiative of the Spanish Administration leaded by the "Fundación Ciudad de la Energía (CIUDEN)".
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2. THE OXYFUEL CIUDEN SPANISH PROJECT

The CIUDEN Spanish Project consists in the development of the oxyfuel technology by means of the construction of a Test Facility with pulverised coal technologies (20 MWt) and coal fluidised bed technologies (20 MWt). Some of the technical characteristics of the Experimental Facility are that it has got a Pilot PC boiler with 2+2 burners in order to see the flame interactions. Besides, it has a flue gas cleaning section for NOx, SOx and particles and a CO_2 Capture Section, including several technologies, such as chemical absorption (amines), flue gas compression and carbonation/calcination eventually. The initial focus is low volatile fuels (anthracites and petroleum coke), which is a differential factor as regards to the other international projects. It has fully integrated preheating train adaptable to any operating scenario, from air-fuel to oxyfuel combustion.[3]
The leader of the Project is the "Fundación Ciudad de la Energía" and the current participants are FOSTER WHEELER (Oxy-combustion Boilers), PRAXAIR (Oxygen Supply and CO_2 Capture), INDRA (Instrumentation and Control), INERCO (Engineering) and INITEC (Detail Engineering and Construction).
The projects that are worldwide developing the oxyfuel technology are shown in the Table 1.

Table1. Different Large Scale Pilot and Demo Projects developing the Oxyfuel Technology

project	MWt	location	start up	boiler type	main fuel
Jupiter	15	USA	2007	industrial	natural gas coal
Ciuden	**20+20**	**Spain**	**2010**	**pilot PC + pilot CFB**	**anthracite petroleum coke**
B&W	30	USA	2007	pilot PC	bituminous coal sub-bituminous coal lignite
Vattenfall	30	Germany	2008	pilot PC	lignite
Oxy-coal UK	40	UK	2008	pilot PC	coal
Pearl Plant	66	USA	2009	pilot PC	bituminous coal
Callide	90	Australia	2010	pilot PC	bituminous coal
Jamestown	150	USA	2013	pilot CFB	bituminous coal
Youngdong	300	Korea	2018	100 MWe PC	coal
Vattenfall	600	Germany	2015	200 MWe PC	lignite bituminous coal

The Research Programme of El Bierzo Test Facility includes two interconnected issues in order to carry out the demonstration of the oxy-combustion technology. One of them is the Scientific Programme, promoted by CIUDEN and performed by relevant Spanish Research Institutions. Another one is the Experimental Programme, performed at the Test Facility in cooperation with research institutions, technology providers and technology users, being the targets the process performance in continuous, part-load operation and load follow-up and the validation of engineering and design tools and process models for scale-up.

The general design criteria of El Bierzo Test Facility has the following main characteristics:

- Modularity: layout as independent but interconnected modules (combustion, oxy-combustion, flue gas treatment…) allowing simultaneous or separate operation for independent study of processes.

- Flexibility: possibility of operation under a wide range of operating conditions, including different coals and combustions from air mode to oxymode.

- Integration: designed to study full process integration of the different units and systems.

- Efficiency: conceived giving great importance to heat integration and performance optimisation without putting into compromise requirements for flexible testing.

- Extension: layout allowing for extensions at a later stage in line with any technological progress and/or strategic development.

- Safety: risk analysis assessment (hazop methodology) to be performed to improve safety and operability of the process. Safety instrumented systems (sis) will fulfil requirements of functional safety standards.

- Monitoring: comprehensive and advanced in-furnace monitoring of the combustion and CO_2 capture processes.

- Plant Auxiliaries: some to be provided from adjacent Compostilla Power Station, (ca. 1200 MWt), owned by the Spanish Utility ENDESA.

- Simulation: conceived to simulate different scenarios of the operation of pulverized coal power stations, offering the possibility of obtaining results and conclusions towards the potential application on utility scale.

As regards to the design criteria, in particular, the modularity, flexibility, monitoring and control capabilities and the planned lay-out, allowing for extensions at a later stage in line with any technological progress and/or strategic developments is well taken care of.

The general Plant Configuration can be observed in Figure 2. It has the following main sections and characteristics:

- Fuel Preparation System Section: It is suitable for a wide range of coals from anthracite to lignite. The initial focus is low volatile fuels (anthracites and petroleum coke), which is a differential factor as regards to the other international projects.

- Combustion Island: It has two boilers which are a pulverised coal boiler of 20 MWt and a circulating fluidized bed boiler of 20 MWt. Besides, it accounts with a fully integrated preheating train adaptable to any operating scenario (from air-fuel to oxyfuel combustion). The PC Boiler has got 2 vertical burners and 2 horizontal burners in order to see the flame interactions.

- Flue Gas Recycle Section.

- Flue Gas Cleaning (FGC) Section, including a Selective Catalytic Reduction (SCR) for NOx, a Wet Flue Gas Desulphuration (FGD) for SOx and particulate control.

- CO_2 Capture Section, including a compression/cooling unit for oxy-flue gases and a chemical absorption unit (amines) for air-flue gases and carbonation/calcination eventually.

- Oxygen Supply Section, including a cryogenic storage and a vaporizing system, and an Air Separation Unit.

- Control Room Section, where it can be controlled all the processes.

3. SINGULARITIES AND COMPETITIVE ADVANTAGES OF THE OXYFUEL CIUDEN SPANISH PROJECT

The main singularities of this Project which make it different regarding the others are the following:

- The depuration of the gases is complete.
- There are two boilers (PC + CFB) in the same location.
- It accounts with 2+2 burners in order to see the flame interactions.
- The main oxyfuel train of the Test Facility is equipped with CO_2 compression and complemented with several CO_2 separation alternatives, such as amines and carbonation.
- The initial focus on low volatile fuels (anthracite and petcoke) provides an additional differentiating factor over other test facilities elsewhere in Europe.

The relevant issues of the initiative and its competitive advantages are:

- Approach consistent with initiatives being developed globally
- Provides support for Spanish contribution to the R&D effort in CCS in Europe and beyond.
- Allows Spain to take a proactive position in the thrust to establish synergistic pan-european initiatives as recommended by the ZEP documents.
- It is conceived for operation in an international context, through coordination with similar actions outside Spain.
- It is to be a focal point for activities in Spain in CCS bringing together representatives of the full industrial chain together with research/academic institutions and government agencies.
- It is fully in line with recommendations of ZEP SRA as CO_2 capture using oxifuelling is recognised one of key areas to be addressed.

4. CONCLUSIONS

The CIUDEN Spanish Project is intended to be one of the 12 European Plants which are able to demonstrate the CCS Technologies by the year 2015.[4]

In conclusion, the installation offers the possibility of operating under a wide range of selected operating conditions, particularly in different degrees of oxycombustion (from air to pure oxygen), allowing for the simulation of different scenarios of the operation of pulverized coal power stations. This would offer the possibility to obtain useful results and

conclusions towards the potential application on utility scale. Furthermore, the layout as independent but interconnected modules (combustion, oxycombustion and flue gas treatment) offers the capability of the simultaneous or separate operation allowing the independent study of each process. The installation has been conceived giving great importance to heat integration and performance optimisation. These aspects should not put into compromise the requirements derived from the range of tests to be envisaged. Moreover, special attention has to be paid to the technical boundary conditions which are not necessarily fully in line with the intended utilisation of proven technology and may be a challenge for potential equipment suppliers.

REFERENCES

(1) International Energy Agency (IEA); World Energy Outlook, OECD/IEA; 2006.
(2) McKinsey&Company; Carbon Capture & Storage: Assessing the Economics. 2008
(3) Cortes-Galeano, V.; Test Facilities for Advanced Technologies for CO2 Abatement and Capture in Coal Power Generation. Presented to the 3rd Workshop of the IEA GHG Oxy-Combustion Network (March 5-6, 2008. Yokohama, Japan)
(4) European Technology Platform for Zero Emission Fossil Fuel Power Plants; The EU Flagship Programme: The key to making CO2 Capture and Storage (CCS) commercially viable by 2020; 2007.