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Techno-Economic Optimization of First Generation Oxy-Fired Pulverized-Coal Power Plant

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Abstract

In this paper, a holistic approach taking into account process economics is employed in order to assess the true potential of first generation oxy-fired power plants. The proposed methodology is carried out in two-steps. The first step consists in the minimization of the energy penalty: an exergy analysis is performed on a conventional base-case oxy-fired power plant in order to identify the possible improvement paths, including structural modifications and thermal integrations. At the end of this step, the process layout leading to a minimized energy penalty is obtained. However, as the introduction of a process modification impacts the plant's CAPEX, each modification highlighted in the previous step is characterized by a techno-economic criterion in order to determine its profitability in a second step. The marginal cost of electricity production, defined as the ratio between additional CAPEX and the net production increase is used for the process modification assessment.

This procedure has been applied on state-of-the-art processes in order to estimate the potential of first generation oxy-combustion power plant. The optimization solely based on an energetic criterion leads to a plant layout with an energy penalty of 6.0 %-pts, which represents a 38 % reduction (the energy penalty of the base case plant is 9.4 %-pts). However, the consideration of economic aspects has highlighted that some of the considered process modifications were not justified on an economic stand point. The optimal oxy-fired power plant, from a techno-economic point of view, exhibits an energy penalty of 6.9 %-pts and allows a 20 % reduction of the CO_2 avoidance cost compared to the base-case oxy-fired plant.

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Keywords: CCS, Oxy-combustion, Techno-economic optimization, Heat integration, Exergy analysis

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Nomenclature

ASU	Air separation unit
CAPEX	Capital expenditure (M€$_{2011}$)
C_{BE}	Breakeven cost of electricity production (€$_{2011}$/MW$_e$)
C_{marg}	Marginal cost of electricity production associated to a process modification (€$_{2011}$/MW$_e$)
CPU	CO_2 compression and purification unit
DCCPS	Direct contact cooler polishing scrubber
ESP	Electrostatic precipitator
f_a	Levelization factor (yr^{-1})
FG	Flue gas
FGD	Flue gas desulfurization unit
FW	Steam cycle feedwater
FWH	Steam cycle feedwater preheater
H	Annual plant operation time ($h.yr^{-1}$)
LCOE	Levelized cost of electricity (€$_{2011}$/MWh)
NPE	Net plant efficiency based on the lower heating value (%$_{LHV}$)
OPEX	Operating expenditure (€2011/yr)
P	Net electric production (MW$_e$)
Q_{comp_ASU}	Heat source – ASU main air compressor intercooler
Q_{comp_FGC}	Heat source – CPU Flue gas compressor intercooler
Q_{comp_CO2C}	Heat source – CPU CO_2 compressor intercooler
Q_{FG_cooler}	Heat source – flue gas at the regenerative heater
Q_{FGD}	Heat source – flue gas before the wet FGD
Q_{DCCPS}	Heat source – flue gas before the DCCPS
Q_{FG_reheat}	Heat sink – flue gas reheater
QPO	Heat sink – primary oxygen preheater
QSO	Heat sink – secondary oxygen preheater
Qoffgas	Heat sink – CPU offgas reheater
QHI-I	Heat source/Heat sink – Steam cycle feedwater preheaters parallel heat exchanger i
SCR	Selective catalytic reduction unit