12CNIT-2022 - EXTENDED ABSTRACT

Carbon recycling in ironmaking through power to gas and oxygen blast furnaces

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Keywords: *Blast furnace; Power to Gas; Rist diagram; Oxyfuel combustion; ironmaking;*

TOPIC: Renewable energies, environmental impact and circularity

1. Introduction

From a carbon-neutrality and economic perspective, green hydrogen and synthetic fuels should be targeted on industries that are inaccessible to direct electrification (e.g., ironmaking, cement and glass). In that sense, the DISIPO project explores the combination of power to gas (PtG) with oxygen blast furnaces (OBF) to decarbonize the iron and steel industry. Power to gas technology consumes renewable electricity to produce H_2, which is then combined with the CO_2 emissions of the ironmaking process to obtain synthetic methane. This synthetic fuel is used in the blast furnace to keep carbon in a closed loop and to diminish the coke input [1]. Since OBF use pure oxygen instead of air for combustion, an air separation unit (ASU) is required. Nevertheless, the electrolysis process of the PtG can provide O_2 to the OBF and decrease the electricity consumption of the ASU. Moreover, the top gas of the OBF is mainly composed by CO_2, CO and H_2 with very little nitrogen content [2], so different integration can be established depending on the gas supplied to the methanation reactor (Fig.1): (a) captured CO_2, (b) treated blast furnace gas or (c) blast furnace gas.

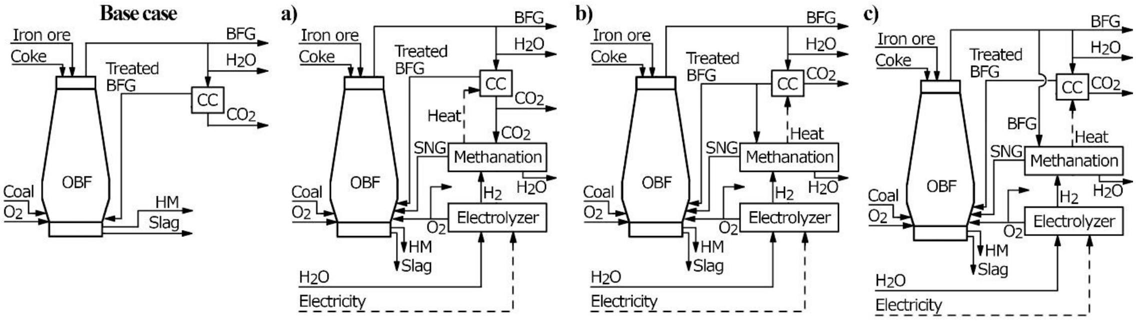

Figure 1. Potential integrations of power to gas with oxygen blast furnaces.

2. Methods

The different potential integrations are studied using the Rist diagram, which is a convenient methodology for predicting changes in blast furnaces when the operating conditions are modified. This methodology is based on the graphical representation of carbon, oxygen, and hydrogen balances through an operation line, restricted by the energy balance, which establishes the participation of these elements in the formation of the reducing gas and its later utilization inside the furnace [3]. Besides, to quantify the most significant aspects that may have an impact on the overall system performance, a total of 17 key performance indicators (KPI) were defined (e.g., CO_2 emissions, energy penalization for CO_2 avoidance, O_2 produced in the ASU). The base case simulation was elaborated using data from [4].

3. Results

One of the most important KPIs is the maximum electrolysis capacity that can be integrated. This is limited by the flame temperature reached inside the blast furnace. The greater the amount of synthetic natural gas injected, the lower the flame temperature (which should not fall below 2000 ºC [5]). In the case of using captured CO_2 in methanation (case (a)), the maximum electrolysis capacity is 0.77 MW/(t_{HM}/h), which would correspond to 424 MW for a blast furnace producing 550 t_{HM}/h. In the case of using treated BFG (i.e., clean BFG without CO_2, case (b)), the maximum electrolysis capacity is 0.54 MW/(t_{HM}/h), corresponding to 297 MW. In the last case, using blast furnace gas directly in the methanation process (case (c)), the electrolysis capacity is limited to 0.62 MW/(t_{HM}/h), which translates into 342 MW for the mentioned size of blast furnace. In the three cases, the total CO_2 emissions are around 1042 kg/t_{HM}, representing that CO_2 has been cut by 10% with respect to the emissions of the base case (which are 1162 kg/t_{HM}). Regarding the energy penalization of this CO_2 avoidance, it is 18.9 MJ/kg_{CO2} for the case (a), 11.8 MJ/kg_{CO2} for case (b) and 13.8 MJ/kg_{CO2} for case (c). This means that the energy penalization can be decreased by 37.6% just by selecting the most convenient configuration of integration. Despite the proposed integration has energy penalizations greater than conventional amine carbon capture (typically 3.7 – 4.8 MJ/kg_{CO2}), it could reduce in return the economic costs thanks to diminishing the coke consumption, reducing the electricity consumption in the air separation unit, and eliminating the requirement of geological storage for the avoided CO_2.

4. Acknowledgements

This project has received funding from the European Union's Framework Programme for Research and Innovation Horizon 2020 (2014-2020) under the Marie Skłodowska-Curie Grant Agreement No. 887077.

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