Integrated Tool for IGCC Power Plants Design

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Abstract:

Expanding economies and global warming are increasingly important and interrelated challenging issues which require cleaner and more efficient power plants designs to comply with sustainable energy demand are required. Integrated Gasification Combined Cycle (IGCC) power plants have an important role, because of their more efficient way of producing energy from fossil fuels. Actions are focused on clean power and H_2 from coal, and bioproducts. So, one of the future of coal-based power generation strategies should be CO_2 transport and storage in order to obtain a purer hydrogen stream. This paper proposes a methodology and supporting tool for estimating plant performance in terms of power effiency and environmental compliance and making an economic assessment for different scenarios. The technical performance has been modeled in Aspen Hysys and Aspen Plus, and models have been validated with real power plant data from ELCOGAS. Comparisons, in terms of power, emissions, efficiencies and costs between a wide variety of plant designs are presented: they enhance differences in raw material, purification units layout, and hydrogen obtention. Results obtained are examined and discussed towards future work.

Keywords: IGCC power plant, conceptual modelling, performance prediction Aspen Hysys modeling, plant layout.

1. MODELLING PERFORMANCE AND PREDICTIONS

In this paper, an integrated platform for different scenarios prediction has been done. On the one hand, Aspen Hysys is the software used as the main platform for building the conceptual model. On the other hand, Microsoft Excel is the tool used for the economic evaluation. The IGCC plant flowsheet can be changed (by the addition or the sustraction of units, or directly by changing the layout of the flowsheet). From the Aspen Hysys model, data such as power, emissions and efficiency can be obtained. From Microsoft Excel calculations it is possible to estimate preliminary costs: direct costs, the total capital requirement, operating costs and the cost of electricity (COE). The two platforms works in an integrated way.

1.1 Conceptual Modelling.

The model is implemented using two main chemical flowsheeting environments: Aspen Hysys and Aspen Plus, which are flexible tools for process simulation by providing thermodynamic models for the estimation of chemical properties and unit operation models for many processes. Aspen Hysys has been chosen as the platform for the overall process simulation because of its capability of accepting custom models as extensions, and its ease of coding. These models could represent complex chemical reactions (COS hydrolysis) or partial gasification steps (pyrolysis). The proposed platform also allows creating new chemical components not included in its database, such as non stoichiometric solids for raw material and char definition. Alternatively, Aspen Plus is used for calculations involving water systems and electrolytes. These ionic models are required to solve phase equilibrium problems for unit operation systems such as venturi scrubbers, SWS or MDEA absorbers. The aforementioned models have been integrated in Aspen Hysys by means of ANN extensions. Data required to train each of the ANN's comes from sensitivity analysis performed within Aspen Plus while the neural network training is carried out using the ANN package provided with Matlab 6.5. Matlab has been also used for gasifier model parameters estimation.

The global flowsheet studied in this work contemplates all components in a typical IGCC layout. It includes a PRENFLO gasifier and a series of purification units, i.e. a ceramic filter, a venturi scrubber, a COS hydrolysis reactor, a sour water stripper, a MDEA absorber and a Claus plant. An ASU is used to obtain oxygen at a purity of 85 wt%. Steam, oxygen and fuel raw materials enter the gasifier and they are converted into syngas, which is cooled down before entering the purification units. Heat is recovered by producing steam in the HRSG, which is used in a steam turbine. The ELCOGAS power plant is designed to produce around 335 MW of gross power with relatively low emissions. SO_2 emissions are controlled by removing sulfur species from the syngas before the combustion in the gas turbine cycle, and producing liquid sulphur. NO_x emissions are avoided by using preventive methods such as nitrogen saturation of the gas also before the combustion. It is worthwhile to mention that ashes are highly removed as slag in the gasification reactor due to high pressure and temperature conditions. Nevertheless, remaining particles are extracted from the syngas by means of filters. In relation to CO_2 and CO emissions, they are assumed to be produced in the gas turbine cycle. Other contaminants such as chlorine, mercury and heavy metals are distributed in the streams flowsheet by using experimental correlations, based on data developed within the AGAPUTE project (Advanced GAs Purification TEchnologies for co-gasification of coal, refinery by-products, biomass and waste, targeted to clean power produced from gas ans steam turbine-sets generator and fuel cells, supported by European Commission, project no. RFS-CR-04006, see Acknowledgements).

The model shows good agreement between simulated results and industrial data for outlet streams of purification gas units: venturi scrubber, sour water stripper, MDEA absorber, and Claus plant, as seen in Fig. 1. The error is a maximum of 18%, which is well within the accepted error margin at the preliminary design stage (25-40%).

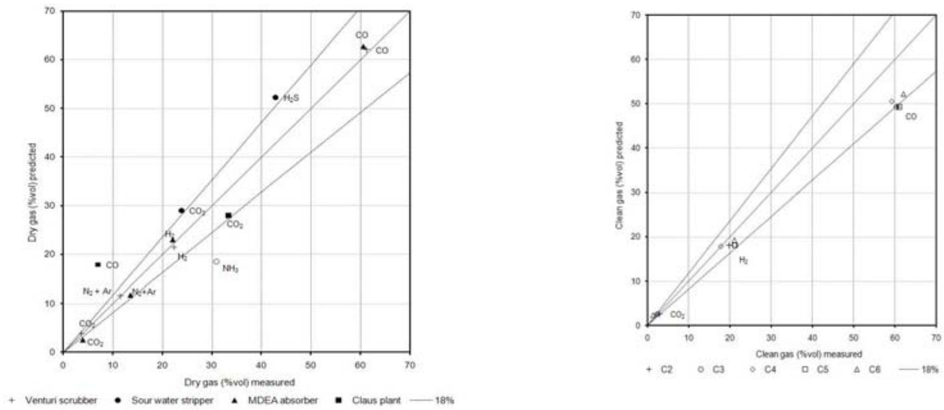

Fig. 1. Purification models validation with real power plant data.

Also, in orther to assure the model confidence, the result of the whole plant has been evaluated by means of the clean gas composition (where again a maximum error of 18% has been observed). See also Fig. 1, right side.

1.2 Best plant design

Election of costs, efficiency and emissions as KPI is directly related to the conception of a profitable gasification plant. The three authors' main criteria for IGCC best design are:

- Economic evaluation: costs à Cost Of Energy (COE).
- Current challenges: environmental impact à Emissions, like CO2, NOx and SO2.
- Process synergy à Energy efficiency.

1.2.1 Results: Scenarios comparison

The scenarios comparison enhance sixteen different cases:

- Eight with different raw materials (coal , coke, a mistureof them, and a mixture of them plus a waste biomass, orujillo)
- Six more cases with different purification gas units layout: by avoiding some units, and also by adding a Selexol absorber or a Dolomite unit.
- Two more by adding a CO2 purification train (with water gas shift reactor, MEA absorber and PSA) and considering hydrogen to the market or to power production.

Pareto curves have been used to compare costs, environmental impact and efficiency of the different scenarios. A methodology to address the work main goal has been proposed: it consists of giving the tactic to find explicit and final solutions for concrete IGCC power plant flowsheet conditions. Costs, emissions and efficiency are considered as selection criteria. In this way, an exhaustive calculation of these parameters is developed in this work.

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