Definition of validated membrane reactor model for 5KW power output CHP under different natural gas compositions

Citation for published version (APA):

Document status and date:
Published: 01/01/2015

Document Version:
Other version

Please check the document version of this publication:
• A submitted manuscript is the version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.
• The final author version and the galley proof are versions of the publication after peer review.
• The final published version features the final layout of the paper including the volume, issue and page numbers.

Link to publication

General rights
Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

• Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
• You may not further distribute the material or use it for any profit-making activity or commercial gain
• You may freely distribute the URL identifying the publication in the public portal.

If the publication is distributed under the terms of Article 25fa of the Dutch Copyright Act, indicated by the “Taverne” license above, please follow below link for the End User Agreement:
www.tue.nl/taverne

Take down policy
If you believe that this document breaches copyright please contact us at:
openaccess@tue.nl
providing details and we will investigate your claim.

Download date: 08. Jun. 2020
Definition of validated membrane reactor model for 5 kW power output CHP system under different natural gas composition

G. Di Marcoberardino*, F. Gallucci, G. Manzolini, M. van Sint Annaland

*Department of Energy – Politecnico di Milano, via Lambruschini 4, 20156 Milano, Italy

Department of Chemical Engineering and Chemistry - Eindhoven University of Technology, P.O. Box 513, 5612 AZ Eindhoven, The Netherlands

*Corresponding author: gioele.dimarcoberardino@polimi.it – www.gecos.polimi.it

Abstract

In the last years, many studies focused on the adoption of membrane reactor in micro-cogeneration system based on PEM fuel cell thanks to the pure hydrogen production. This work deals with (i) the design of a FBMR flexible towards different NG compositions (ii) and its integration in PEM based systems of 5 kW power output system. Indeed the variation of NG composition has a big impact on the performance of the micro-CHP system and fuel processor life time. Four typical NG compositions from reference European countries are considered in this study 2 different membrane reactor model are compared: the first is a 1D phenomenological model, the latter is inside a model of the overall PEM based micro-CHP in Aspen Plus. Furthermore, since the overall PEM based micro-CHP system is modelled using Aspen Plus®, the phenomenological model is used to validate the fuel processor implemented in the CHP model. In this case, the FBMR is modelled by adapting a series of equilibrium reactors followed by hydrogen extraction.

Micro-CHP Layout flexibility

The micro-CHP system is designed to generate 5 kWel and 6.2 kWh of hot water (where the cooling circuit temperatures are 60/40 °C). At design conditions, the net electric efficiency and the total efficiency are respectively 40.1% and 89.2%. The fuel processor is based on fluidized autothermal membrane reactor (600 °C and 8 bar) fed with NG, producing pure hydrogen flow (@ 0.3 bar) without the use of sweep gas. An air flow, below the stoichiometric value, burns a fraction of NG in order to sustain the endothermic SR reactions. From the vacuum pump, the H2 flux feeds a dead-end LT PEM FC (@ 75 °C) cooled by the water heat recovery loop.

After the design of the FBMR and the definition of the main CHP parameters using the UK case (average EU-NG), layout flexibility and different control strategies for the other NG compositions are investigated.

Membrane Reactor Model (1)

The phenomenological 1D membrane reactor model allows the simulation of FBMR for separation of hydrogen from a reacting mix undergoing steam methane reforming (SMR) or autothermal reforming (ATR). The steady state overall (bubble and emulsion phases) component mass conservation equations and the total volume balance (to calculate the excess velocity) have been formulated, taking chemical transformations in the emulsion phase and a net gas production due to the chemical reactions and gas removal via membranes into account.

Membrane Reactor Model (2)

The membrane reactor, implemented in Aspen Plus®, is discretized in a series of 10 reactors and separators. Each reactor is set to equilibrium conversion (SRB/WGS reactions + Total Oxidation at the inlet) by Gibbs free energy minimization. In the separators, hydrogen is extracted (infinite perm-selectivity is assumed) according to the permeation expression. In both the models, temperature profile along the reactor bed is uniform both radially and axially.

Results

Performances of the micro-CHP system under the 4 EU-NG qualities are reported in the table. Since the reactor operating pressure is constant for all the cases, the only parameter control is the air flow \( \dot{V}_{\text{air}} \). The NL case has the low electric efficiency due to the large amount of \( \Delta_{\text{H}} \) in the NG; this implies an higher power input and higher auxiliary losses. On the other hand it has the best thermal recovery. The other 3 cases have quite similar performances even if the ES case, with the big amount of hydrocarbons heavier than methane, has the best electric performances.

This work is funded within FERRET project as part of the European Union’s Seventh Framework Programme (FP7/2007-2013) for the Fuel Cells and Hydrogen Joint Technology Initiative under grant agreement nº 621181. Note: “The present publication reflects only the author’s views and the FCH JU and the Union are not liable for any use that may be made of the information contained therein.”

Aspen Consultant

12th International Conference on Catalysis in Membrane Reactors – 22-25 June 2015, Szczecin, Poland