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Investigation of cryogenic technique for synthetic natural gas upgrading

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ABSTRACT

Bio-LNG which is produced by liquefaction of synthetic natural gas from biomass (bio-SNG) is a valuable renewable fuel as it has high energy density and transportability. Cryogenic technology is a promising option for integration of the gas upgrading and liquefaction systems with the main biomass gasification and methane synthesis plant. This study investigates the feasibility of this technology for future commercial bio-SNG production plants based on indirect gasification technology, similar to that adopted by Göteborg Energi for the GoBiGas project. Simulation program Aspen Plus and pinch analysis tool Pro_PI are used to compare conventional gas cleaning and liquefaction technology and cryogenic technology. The cryogenic unit achieves the targeted product specifications and capacity, and the calculated performance is comparable to published data for commercial units. The results show that the integrated plant with cryogenic technology has a higher power requirement than the plant with conventional technology. Cryogenic technology is still under development, therefore there is a high potential for performance improvement by application of energy efficiency measures. In addition, high purity liquid CO_2 is produced at very low temperature as a by-product which could generate additional revenue.

Introduction

There is an ecological overshoot in which society is using more resources than nature can regenerate causing environmental and economic consequences. These problems have resulted in new policies that have stimulated research leading to variety of solutions ranging from technical improvements to new process routes for energy conversion processes.

The conversion of energy from renewable sources plays a major role for energy supply security as well as to reach climate and energy targets that were established by the European Commission's directive on the promotion of the use of energy from renewable sources (the "Renewable Energy Directive"). These mandatory targets are often referred to as the 20-20-20 targets which are planned to be achieved by 2020. EU energy consumption from renewable sources is set to reach 20% [1].

Renewable fuels as renewable energy source refer to fuels produced from renewable biomass or waste feedstock. They can be used for heat or electricity production and as a motor vehicle fuel. Bio-SNG (synthetic natural gas produced from biomass) has similar quality to fossil natural gas with advantage of being produced from renewable sources.

Bio-SNG can replace fossil natural gas; however, it has to be cleaned and upgraded before final use. Among other commercial upgrading techniques, cryogenic method has

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drawn attention recently. It makes use of the difference in condensation points of gases in a bio-SNG mix; gases are separated from each other by consecutive cooling, condensation and separation. It is an alternative for both gas upgrading and bio-LNG (renewable liquefied natural gas) production with added benefit of producing high-purity liquid CO_2 as a by-product. Moreover, cryogenic technology has low maintenance requirements since it does not require extra materials such as membrane or chemicals as other commercial upgrading techniques do. Although cryogenic technique has relatively high power demand, integration of gas upgrading and liquefaction has a great potential to overcome this drawback. Bio-LNG is a valuable product since it has higher energy density compared to bio-SNG. Thus, it is easier to transport which is highly favorable especially in the case of use as a vehicle fuel.

Methodology

A literature study was conducted in order to gather data required to establish a simulation model of a bio-LNG production process. Material and energy balances are solved in the commercial flowsheeting software Aspen Plus from Aspen Technology. Process integration tool pro_PI is used to conduct pinch analysis with simulation results for both cases so that theoretical maximum work outputs are investigated.

In this study two different cases are defined to investigate cryogenic technique for gas upgrading; base case and integrated case. In base case, bio-LNG is produced in a liquefaction plant located immediately downstream of the main bio-SNG process. In integrated case a cryogenic unit is implemented directly within the process instead of conventional gas upgrading technology. Both processes are based on capacity assumption of 100 MW of bio-LNG and are inspired by GoBiGas design with addition of gas liquefaction unit [2]. Schematic representations of base case and integrated case can be seen in Figs. 1 and 2, respectively.

The major difference in the designs is upgrading unit. In base case, it is kept as the same as in GoBiGas project which is chemical absorption technique applied before methanation while in integrated case cryogenic method is applied before methanation.

Process modelling

Aspen Plus provides a rich property database, equations of state for different conditions and different models for common unit operations.

Biomass inlet consists of wet wood and it is modelled as a non-conventional solid [3]. Raw bio-SNG is produced after gasification and gas cleaning and it mainly consists of carbon dioxide, CH_4 and trace amounts of hydrogen, carbon monoxide and water. Other existing components during the process that are removed are char, hydrocarbons, tars, sulphur compounds and trace compounds such as N_2 and HCI. Final product is bio-LNG that is primarily CH_4 in liquid state.

In this study, cryogenic unit for gas upgrading and liquefaction processes are simulated. The rest of the process simulation is based on Arvidsson et.al [4]. Liquefaction process modelling is considered for base case whereas cryogenic technique modelling together with liquefaction is considered for integrated case.

Process specifications and assumptions.

Bio-SNG production is based on an existing design inspired by GoBiGas project.

Production capacity: 100 $MW_{bio\text{-}LNG}$.

Final delivery conditions: 7,5 bar and −163 °C.

Purity requirements for the liquefaction of bio-SNG: 50-125 ppm CO_2.

Base case

Employed technology for bio-SNG liquefaction is based on a reverse nitrogen Brayton cycle. Pressure is a key variable in liquefaction process. In order to study the advantages and disadvantages of liquefying at high pressure, two designs that operate at different pressures are modelled in Aspen: high pressure case at 40 bar and low pressure case at 8 bar that is in the range of the delivery pressure in GoBiGas plant (5–10 bar).

Bio-SNG coming from drying and gas cleaning and entering the liquefaction process is at 8 bar, therefore liquefaction occurs at −130 °C (Fig. 3).

First, low pressure N_2 cools down bio-SNG and high pressure N_2 to −92.5 °C in order to achieve desired specifications. In the second cooler, liquefaction of bio-SNG occurs. Coolers decrease refrigerant temperature to ambient temperature and the pressure in the compressors is in ranges determined in process specifications.

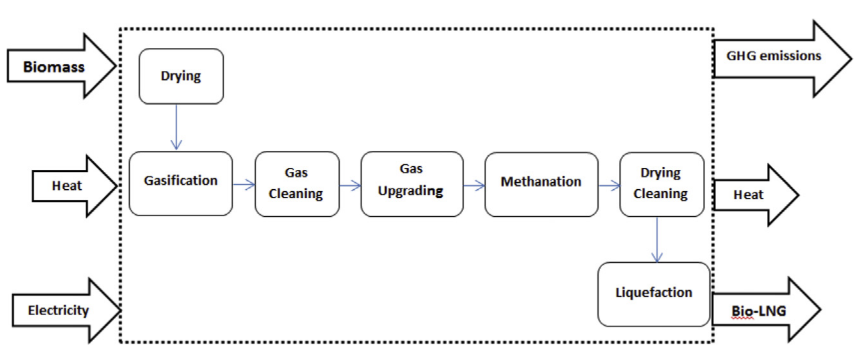

Fig. 1 – Schematic representation of base case bio-LNG production process.

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