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Renewable Gasfield – a Biogas to SNG demo plant

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Abstract

The Project Renewable Gasfield connects the long-term storage of renewable excess power (from PV) and synchronized regional production of green gases such as hydrogen and synthetic natural gas (SNG). These green gases can be locally used in different sectors or can be fed into the existing gas grid. The so called Power-to-Gas technology (electrolysis and methanation plant) will be assembled within the framework of Renewable Gasfield and "Vorzeigeregion Energie" in the southern part of Styria.

A newly erected photovoltaic plant feeds green electricity to PEM electrolysis for the generation of green hydrogen. The electrolysis is coupled with an innovative, load-flexible methanation plant in which raw biogas, without an upstream CO_2 separation, will be transformed with hydrogen to green synthetic natural gas. As output gases renewable hydrogen, usable for the sectors industry and mobility, and green synthetic natural gas for feed-in into the existing gas grid will be generated.

For the dimensioning of the load-flexible methanation plant variations of the process parameters were tested in the pilot methanation plant at Montanuniversity Leoben. The generated research data provide a basis for a successful realization and commissioning of the demo plant.

Introduction

Corresponding to #mission2030 Austria actively pursues the reduction of the emissions of greenhouse gases and the expansion of renewable energies. The decarbonisation of energy supply will be driven by the increase of installations of wind and photovoltaic plants. [1] Due to the fluctuating character of renewables, long term storage capacities for a guaranteed supply need to be constructed. [2] The Austrian gas grid offers enormous storage potential and enables the transport of large quantities of hydrogen and green synthetic natural gas.

The Wiva P&G targets a strongly hydrogen based energy system in Austria. Synergies and sector couplings for electricity, gas and heat enable efficient energy distribution with reference to the regional conditions and the demand of households and industries. Hydrogen's fields of applications depending on the production, storage and distribution, transformation to green synthetic natural gas or incineration and reconversion will be analyzed, realized and developed for different branches. [3]

"Renewable Gasfield" – a demo plant

The focus of Renewable Gasfield is on the modularity of the plant engineering which considers the regional circumstances. An expansion or adaption of plant components will be possible in the future. A more detailed description of the plant concept is shown in figure 1.

In a community in southern Styria a 1 MW_p PV plant will be erected for the production or renewable energy to supply a 1 MW_{el} electrolysis for the generation of green hydrogen. The decoupling of power generation and hydrogen production is realized with a 30 bar hydrogen intermediate storage after the electrolysis. Starting from the 30 bar intermediate storage hydrogen can be used in two different ways. Either the hydrogen is compressed to 450 bar and filled in trailers for the transfer to industry, businesses or the mobility sector, or the green hydrogen will be fed into a load flexible, catalytic methanation plant. The product gas of a biogas plant, containing CO_2 and bio-methane, will be converted in situ to synthetic natural gas which is suitable for a safe transport in the local existing gas grid. [4]

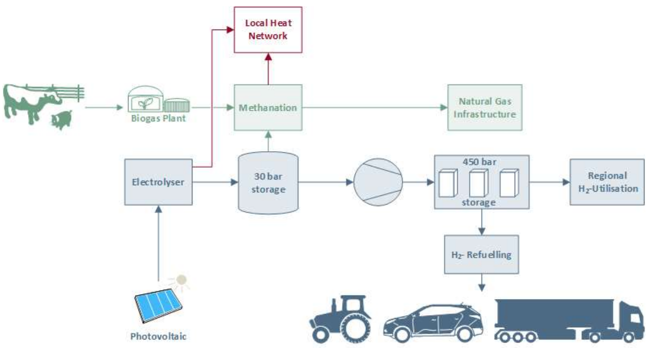

Figure 1: Concept of the project Renewable Gasfield [4]

The overarching goal of the project Renewable Gasfield is the interaction of different renewable energies to achieve the fulfillment for industry, businesses and households demand. The regional infrastructure will be modified to meet high requirements of a green energy supply in respect to regional circumstances.

The setup of the planned methanation plant is designed as follows and depicted in figure 2. The product gas from the biogas plant consisting of approx. 45 vol.-% CO_2 and 55 vol.-% CH_4 is cleared in an adsorber from the catalyst poisons (ammonia or hydrogen sulphides) and then compressed to 10 bar. The hydrogen and the biogas flow into a two staged, honeycomb catalysts filled methanation plant. Due to the exothermic nature of the methanation reaction an air-cooled heat exchanger is installed downstream after each reactor stage. Before feeding into the gas network, the synthetic natural gas is purified in a polymer membrane. A product gas stream with > 96vol.-% CH_4 needs to be guaranteed to meet the current directive's quality requirements (see ÖVGW G 31 [5]). The retentat flow will be circulated and fed in again the first stage of the methanation plant. [4]

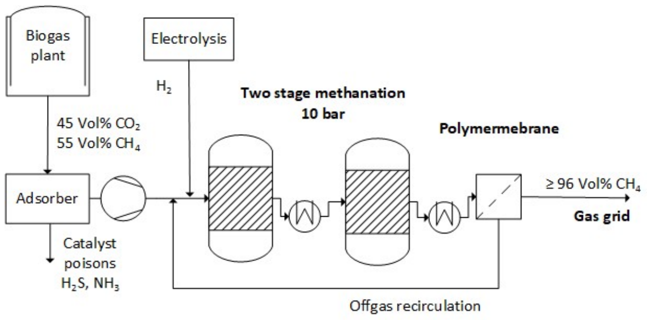

Figure 2: Flow chart of planned components of methanation process

The load flexible methanation plant will equipped with a proprietary honeycomb catalyst on which the catalytic active nickel will be applied in a two staged process. Moreover the ceramic basis structure of the honeycombs offers a good heat storage capacity and temperature resistance. The schematic reactor profile can be seen in figure 3. The split of the reactor in compartments – yet to be determined how many – enables a load flexible operation due to the fast-responding stand-by performance of the honeycombs. According to load conditions all compartments – at full load operation – or individual compartments – at low load operation – can be operated whereas a cyclical switch to more or less compartments is possible. The number of installed honeycombs per compartment also will be defined in the future.

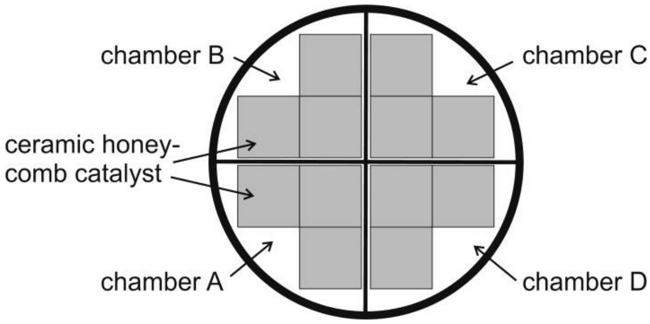

Figure 3: Methanation reactor profile with honeycomb catalysts

Material and Methods

As preparation for the successful implementation of the honeycomb catalysts comparable test runs will be carried out in the pilot methanation plant of the Chair of Process Technology at Montanuniversity Leoben. Various process parameters will be tested in small scale following the future operation strategy of the demo plant in the southern part of Styria. The pilot plant consists of three fixed bed reactors connected in series whereas single stage test runs are also possible. The maximum input flow is 50 l/min (STP), the pressure level is configurable between 1 to 20 bar and each reactor is limited to 700°C operation temperatures due to the material characteristics. A variable synthetic gas mixture serves as input and the product gas mixture passes a gas analysis from ABB for determination of the composition.

The fixed bed reactor can be either filled with commercial bulk catalyst (f.e. Meth® 134) or with honeycomb catalysts. The following figure 4 shows the schematic profile of the reactor setup with an installed honeycomb catalyst at the Chair of Process Technology in Leoben. The input gas mixture flows through the reactor from bottom to top and passes first a layer of ceramic inert balls for an even distribution of the gas flow through the bed. The catalyst (honeycomb or bulk catalyst) is located above the inert bed. For the suppression of bypass flows, the honeycomb is wrapped with isolation wool. Thermocouples are introduced to the catalyst bed to determine the temperature distribution caused by the exothermal methanation reaction.

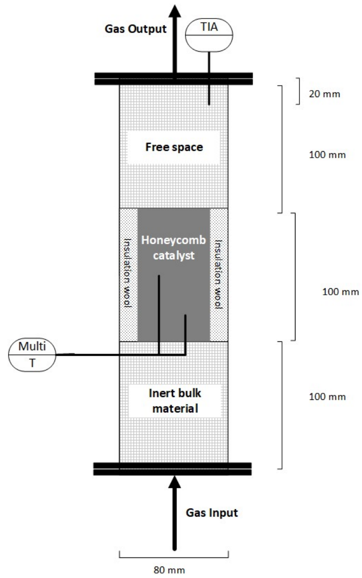

Figure 4: Schematic profile of the reactor setup at the Chair of Process Technology in Leoben

In case the reactor is filled with commercial bulk catalyst another layer of ceramic inert balls is placed on top of the catalyst to prevent discharge of catalysts pellets into the piping system.

Cordierite $Mg_2Al_3[AlSi_5O_{18}]$ is the main structure component of the monolithic honeycomb catalysts which offers large pores but low specific surface (approx. 0,3 m^2/g). To higher the specific surface a carrier material needs to be applied on the honeycombs. Inorganic oxides like γ-Al_2O_3 (boehmite) provide the needed specific area of around > 100 m^2/g. In the second dip coating step the catalytic active nickel is applied. [6] Both stages, the uncoated cordierite honeycomb and the two times wash-coated honeycomb with active nickel, are shown in the figure 5. The honeycombs are calcined at 1.000°C before and at 600°C after the dip coating procedures. Used honeycomb catalysts for test runs at the pilot plant of Montanuniversity Leoben measure 50x50x100 mm^3 at a cell density of 100 cpsi (channels per square inch). To ensure the catalytic activity of the honeycombs during test runs, the honeycombs are preheated in the reactor to 200°C. Afterwards the honeycombs will be purged with synthetic hydrogen to transform the nickel-bonding into metallic active nickel.

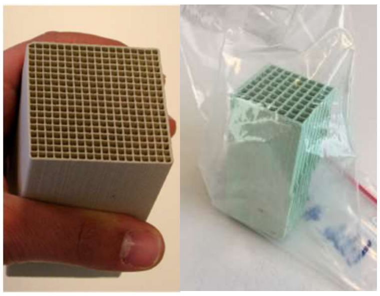

Figure 5: Process stages of honeycomb catalyst (left: uncoated cordierite honeycomb, right: after two staged wash-coating process) [7]

Results

To examine the behavior of the biogas feed gas for the methanation, a series of first test runs with commercial bulk catalyst were carried out. For this purpose two reactors connected in series were used. As input a synthetic gas mixture of biogas (45 vol.-% CO_2 and 55 vol.-% CH_4) was dosed at 10 bar operating pressure. The gas hourly space velocity (GHSV) was varied between 2.000, 3.000 and 4.000 h^{-1} and describes the ratio between the flow rate and the catalyst volume. Hydrogen was added from stoichiometric ratio (0% surplus → H_2/CO_x=1) up to an over stoichiometric ratio of 8% surplus. (H_2/CO_x=1,08)

The results under the above mentioned conditions are plotted in figure 6. On the x-axis the pressure level, GSHV variation and hydrogen surplus (1-1,08) can be found and on y-axis the CO_2 conversion results as well the mean reactor temperatures of each reactor (R1 and R2) are plotted.

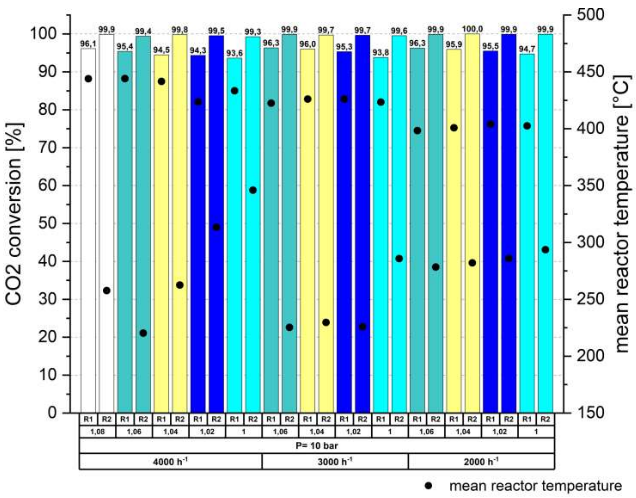

Figure 6: Results of methanation test runs at the pilot plant under Renewable Gasfield conditions with a synthetic biogas input gas mixture

It can be seen that with increasing the H_2 surplus, the conversion in R1 slightly increases in all three GHSV stages, on example of GHSV=2000 h^{-1}, from 94,7% up to 96,3%. But on the other hand, with increased GHSV the conversion decreases in each R1, due to the higher flow rate and therefore higher amount of the reactive gas introduced in the reactor. Consequently the mean reactor temperatures in R1 also increase with the increased GHSV. Due to the high conversion of the CO_2 in the first reactor stage, the mean reactor temperatures in R1 are in general higher than in R2. Nevertheless, the achieved CO_2 conversion rate after the second reactor is always higher than 99,3 % and hence satisfying.

The same test parameter will be repeated with wash coated honeycombs as catalyst. The commercial bulk catalyst sets the performance benchmark for the proprietary wash coated honeycombs with boehmite and nickel.

Conclusion & Outlook

At the moment the plant configuration is in planning phase. Besides, the project consortium is in regularly meetings with local authorities to fulfill statutory and official requirements as effectively as possible. In the upcoming months the detailed plant design for the electrolysis and the load-flexible methanation plant will be fixed in order to begin as soon as possible with the erection of the plant components. The startup and first field test runs are planned for 2021.

Parallel methanation test runs will be conducted in the pilot plant at the Chair of Process Technology at Montanuniversity Leoben. The long-term stability and activity of both catalysts, commercial bulk and wash-coated honeycomb catalysts, will be evaluated throughout the laboratory investigations. Basically the methanation test runs provide a satisfying CO_2 conversion rate of a synthetic biogas mixture of > 99,3 %. More detailed verification of the planned process parameter i.e. the economically viable hydrogen surplus for a sufficient high CO_2 conversion will be conducted also for both catalysts. Depending on the performance results of the honeycomb catalysts during the laboratory experiments adaptions in the wash coating procedure will result in the future.

Expression of thanks

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