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Renewable Gasfield

Lessons Learned from Commissioning towards Stable Operation

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Abstract. Two years ago, the concept of the Renewable Gasfield Gabersdorf was introduced during the ISEC 2022 conference. Now, two years later, we are able to present our “real-life” experience which we made in the meantime, covering the authority engineering process, the construction period and – most important – the start-up and commissioning process.

In this period not only the P2G-plant was set into operation, but we also saw an increasing number of hours with a surplus of solar electric power produced in the surrounding countryside. So, at several hours throughout the year, the electric power output of the already existing solar parks had to be reduced in order to maintain a stable electric grid.

Although the PEM-electrolyser with 1.4 MW total electric power uptake is still to be considered as a small-scale project, it becomes obvious that the concept of producing green hydrogen and then using this hydrogen to upgrade raw biogas to pure biomethane will be a perfect concept to store a surplus in electric power permanently in the existing natural gas grid.

Keywords: Green hydrogen, Methanation of biogas, injection into gas-grid, commissioning

1. Introduction

In the Styrian research project “Renewable Gasfield” a power-to-gas (P2G) plant was built in Gabersdorf near Leibnitz [1]. It shows the role of renewable hydrogen and biomethane as important core components in a future energy model region considering sector coupling.

Green hydrogen is produced by a 1.4 MW_{tot} PEM electrolysis with a production capacity of 210 Nm^3 H_2/h or 140 tons/a. The energy is provided mainly through certified green electricity (mainly wind power) from the grid but also by on-site photovoltaic modules (750 kWp). The produced green H_2 is stored at 30 and 500 bar and can be filled into distribution trailers in order to be transported to nearby industrial sites or research facilities.

For the methanation, biogas is delivered from the nearby agricultural biogas plant. Roughly 260 ha of agricultural land is used to renewably grow the processed crops for the generation of 260 Nm^3/h biogas. The biogas contains around 52 v% CH_4 and 46 v% CO_2, is converted into 500 kW electric power and also roughly 550 kW thermal power in a CHP unit. The thermal power is used in a local heating network.

21 Nm³/h of the biogas is withdrawn and transported to the new P2G plant. After dehumidification and purification with activated carbon, the biogas is fed into a catalytic reactor together with 40 Nm³/h of hydrogen from the electrolysis for direct methanation. The catalytic reaction takes place on a specialized catalysator at medium temperature and pressure levels. The produced biomethane (21 Nm³/h) with a remaining share of hydrogen (< 10 v%) fulfils the requirements of the Austrian gas network (ÖVGW GB 210-2021) and is injected into the local natural gas grid.

- (1) photovoltaic system
- (2) three transformers
- (3) two electrolysis containers
- (4) low-pressure storage
- (5) two compressor containers
- (6) medium-pressure storage
- (7) trailer filling station
- (8) methanation
- (9) feed-in system for SNG
- (10) electric and control container
- (11) information centre

Figure 1: General view with indications of main components (total area: 9.450 m²)

2. Timeline

Looking back at the timeline we see a quick and straight forward authority engineering process which lasted from March 2021 until April 2022. The construction on site started in April 2022 and was completed after only six months already in September 2022. Start-up followed and the commissioning was completed in March 2023.

Figure 2: bird-view of the P2G-site

Parallel to the construction phase a HAZOP-study on the intersections of the individual parts of the plant was undertaken. In the HAZOP process engineers from all involved contractors were involved. The HAZOP study was necessary to supplement the suppliers CE markings, but the issuing of a declaration of conformity by the system operator turned out to be not necessary.

3. Results and discussion

Based on the experience of the start-up process of all components proofed their promised efficiency. This and the overall efficiency will be reported in detail during the conference.

Some basic numbers are given here:

Electrolysis

A containerized Proton-Exchange-Membrane (PEM) unit was built, it features

- Production of 210 Nm^3 H_2/h or 19 kg H_2/h
- Gas pressure: < 30 bar
- el. Power input: max. 1.4 MW incl. auxiliaries
- Water consumption: 260 kg/h (or 13.7 kg/kgH_2)
- Water treatment (RO, ion exchange) → ultrapure water
- Hydrogen must be dried and is delivered in quality 5.0
- Oxygen is blown off – but must be used as a very valuable resource in future large scale plants!
(for e.g. aeration of WWTP, oxygen biomass combustion)

Results:

- Electric power consumed: 994 kW (without auxiliaries of container)
- Yield of hydrogen: 210 Nm^3/h @ up to 30 bar

- Higher heating value H2: 3,54 kWh/Nm³
- => Energy efficiency: (3,54 x 210) / 994 = 74,8%

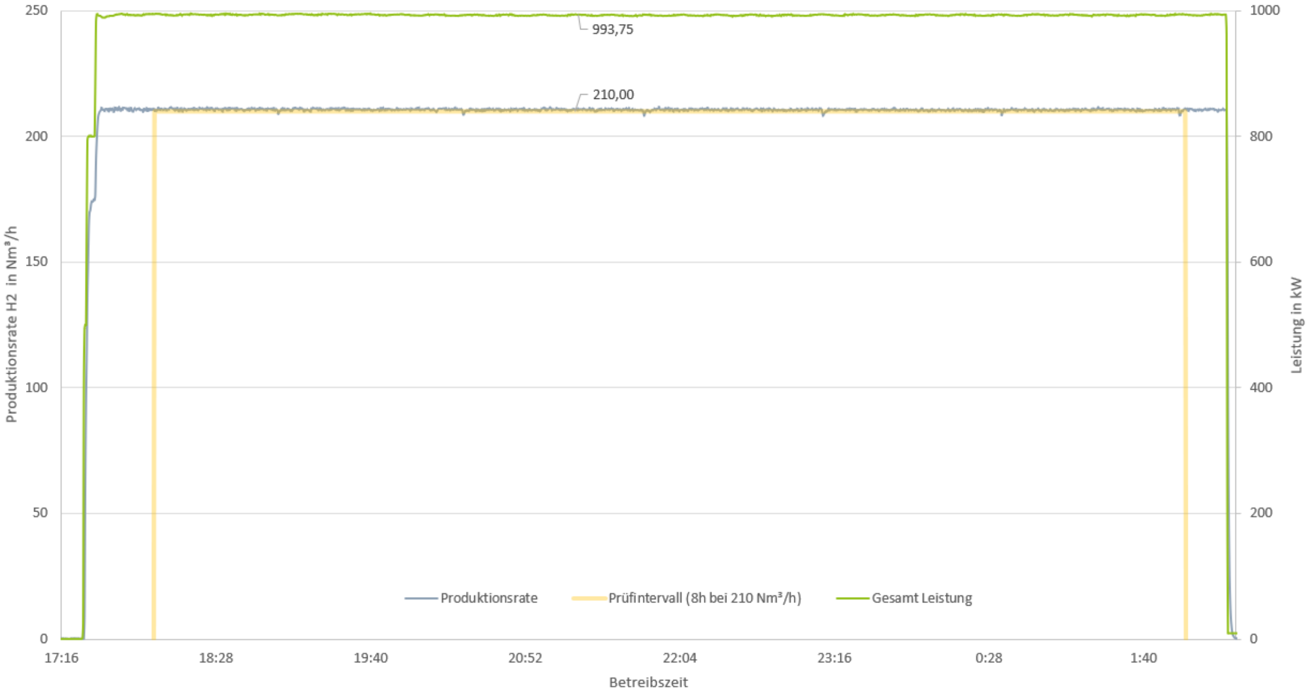

Figure 3: Consumed electric power and hydrogen production during test-run

- Time to reach full H_2-production: 2 min

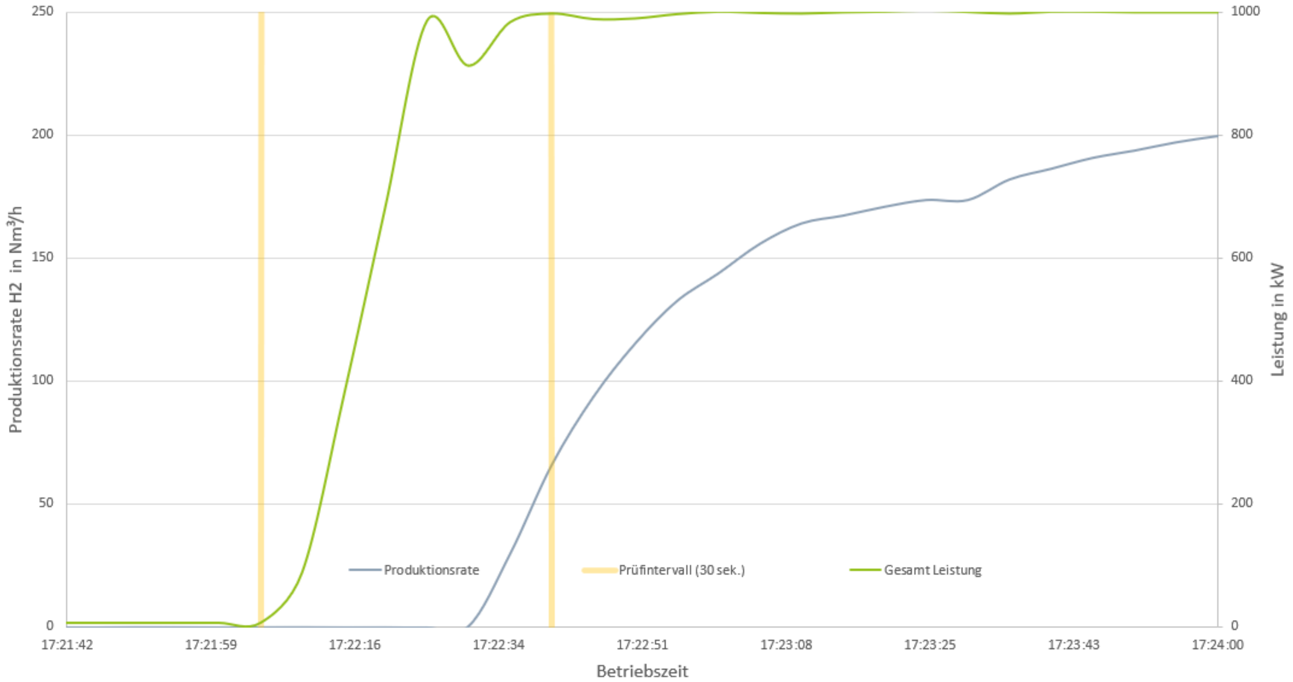

Figure 4: Time to reach full H_2-production

- This fast reaction time is essential for implementing the electrolysis concept to use any surplus in renewable volatile energy from local solar or wind power

Methanation of Biogas using Hydrogen

The data given is based on a test run on Dec. 14th, 2022, 10:00 – 11:00.

Results:

- Biogas consumed: 19,4 Nm³/h with 49,4 v% CH_4, 49,0 v% CO_2
  energy input: E = 96 kWh
- Hydrogen consumed: 38,1 Nm³/h
  energy input: E = 135 kWh
- Efficiency of hydrogen production in ELE from renewables (see above): 74,8%
- Renewable electricity demand for green hydrogen
  energy input: E = 180 kWh
- Electric energy consumed:
  energy input: E = 24,1 kWh
- Product gas: 19,7 Nm³/h
- Methane in product gas: 17,7 Nm³/h (89.8 v%)
  energy output: E = 177 kWh
- Hydrogen in product gas: 1,77 Nm³/h (9.0 v%)
  energy output: E = 6,3 kWh
- Heat from exothermal reaction (energy output): E = 19,5 kWh @ 150 °C
- => Energy efficiency: (177 + 6,3 + 19,5) / (96 + 180 + 24) = 67,5%
- Efficiency in terms of Carbon-usage (material efficiency): 100%

These efficiency numbers can be compared to the separation of biomethane by using membranes. In this “state of the art” process the following numbers are valid:

- Energy efficiency: 93,4%
- Efficiency in terms of Carbon-usage (material efficiency): 53%

Although the energy efficiency is far better in this “conventional” biomethane purification process compared to the presented methanation process, a lot less carbon is recovered! If we want a better material carbon usage, we will have to opt for this way!

General remarks

Due to the nature of this innovative full-scale renewable energy research project several problems arose and had to be solved.

The commissioning process involved several players, among them notified bodies and public authorities. All these stake-holders must be managed in time and well-coordinated in order to complete such a plant in time. Even small inaccuracies, such as a lack of confirmation of conformity of a minor unit, can significantly delay the acceptance process and thus the commissioning of the entire system. Likewise, unexpected defects in simple seals can lead to an undesirable chain of errors if no reliable problem detection measures are implemented.

On the other hand, the combination of green hydrogen with a biogas production plant offers the urgently needed potential for storing volatile green electricity and – at the same time – stabilizing the grid with acceptable overall energy and material efficiency.

5. Conclusions and outlook

In Austria biogas is derived from over 300 local sites already now. It is produced continuously 24/7 throughout the year!

Most plants show an availability of more than 92% related on full production hours.

There are several cheap and reliable biogas-resources available:

- Organic household waste
- Communal sewage sludge
- Landfill gas from old mixed waste landfills
- Numerous organic industrial residues
- Renewable agricultural crops and residues

The production of green hydrogen and CO_2-Methanation of biogas yields biomethane which can be injected and stored in the existing gas grid.

A study by Energieinstitut Linz und Montanuniversität Leoben [2] shows that long-term storage of CH_4-energy in the existing Austrian gas grid is feasible! An amount of ~ 17 TWh of energy can be produced and stored. This is a relevant number and biomethane, as a very valuable and storable resource, should mainly be used for industrial processes. In addition, up to 10 v% of green hydrogen can be fed directly into the gas grid.

This will make it possible to transfer the summer surplus of renewable solar and wind energy to the winter season and it will allow us to become less depended on fossil resources, but it´s not an easy task and we will have to invest a lot of mental and financial energy to develop the necessary know-how, but

it will be worth it!

Data availability statement

The presented data is based on restricted third-party data. The presented data was formally agreed among the project partners to be made available to the public.

Underlying and related material

Other material was used for this article but it is restricted from further publication.

Author contributions

All authors were actively involved in this project as well as in writing this article.

Competing interests

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If you want to acknowledge persons or institutions you can do so here.

References

[1] Mayr B., Sieder T., Salbrechter K., Neumann K., Lehner M. (2022), RENEWABLE GASFIELD – A HOLISTIC POWER-TO-GAS APPROACH WITH PEM ELECTROLYSIS AND CATALYTIC METHANATION, ISEC Conference, Graz, A

[2] Energieinstitut Linz und Energieverbundtechnik Montanuni Leoben. „Erhöhung des Einsatzes von erneuerbarem Gas im österreichischen Energiesystem“, Executive Summary, Mai 2020 https://www.gaswaerme.at/media/medialibrary/2021/03/FGW_Greeningthe_Gas_EIJKU_MUL_stat20052020_executivesummary.pdf, seen on April 4th, 2022)