Storage of volatile renewable energy in the gas grid applying 3-phase methanation

Manuel Götz*, Dominic Buchholz, Siegfried Bajohr, Rainer Reimert

* Phone: +49 721 608 4 4815, email: goetz@dvgw-ebi.de

Objectives

- **Strong increase of wind power and photovoltaics**
  - World total installed capacity of wind power

- **Drawback: both are strongly fluctuating**
  - Power input and output of electricity grid have to be in balance permanently
  - Large storage capacity necessary

**Electrolysis**

- **Use of surplus electricity for water electrolysis**
  - Operation at elevated pressure (20 - 30 bar)
  - PEM electrolysis can handle volatile electricity

Power storage

- **Technologies with large capacity and storage duration of days or weeks:**
  - Pumped storage hydropower
  - High efficiency up to 85 %
  - Capacity very limited in most countries
  - Compressed air energy storage (CAES)
  - Low energy density
  - Diabatic: poor efficiency of < 50 %
  - Adiabatic: not yet state-of-the-art
  - **Power-to-Gas**
  - CH₄ as chemical energy carrier
  - Highest energy density
  - Efficiency up to 64 % (from power to CH₄)

- **Gas grid is well structured and developed in many countries**
  - Energy distribution
  - Large storage capacity of > 3600 TWh

**CO₂/CO sources**

- Carbon sources in all scales available

- Small scale: 1,000 m³/h
  - Biogas plants
  - Biomass gasification

- Middle scale: 5,000 m³/h
  - CHP

- Large scale: 10,000 m³/h
  - Chemical industry

Process chain “Power-to-Gas”

- **CO₂/CO source**
  - Biogas plant etc.

- **CO₂ (CO)**
  - therm. energy 200 – 300 °C

- **H₂**
  - dynamic PEM

- **H₂-storage (optional)**

- **3-phase-methanation**

- **CH₄, H₂, etc.**
  - gas grid
dynamic or stationary

**Fundamentals of methanation**

3 H₂ + CO → CH₄ + H₂O(liq) \( ΔH^o = -206 \text{ kJ/mol} \)

4 H₂ + CO₂ → CH₄ + 2 H₂O(liq) \( ΔH^o = -165 \text{ kJ/mol} \)

- **Removal of reaction heat is the main issue**
  - State-of-the-art methanation reactors:
    - Fixed-bed and fluidized-bed reactor
  - **Novel concept: 3-phase methanation**
    - Reactor is filled with an inert liquid
    - Catalyst (< 100 µm) is suspended in this liquid

Advantages of 3-phase methanation

- Only one reactor necessary
- High heat capacity of the liquid
- Simplified removal of waste heat
- Isothermic operation possible
- Buffers the effect of fluctuating feed streams

Aim of development

- Identification of operating parameters for optimized mass transfer in the liquid phase

Optimization of liquid-side mass transfer:

\[ \frac{V_f}{V_p} = k_l a (c_{liq} - c_{eq}) \]

1. Increase \( k_l \)
2. Increase \( a = \frac{6 \cdot c_{liq}}{d_{bubble}} \)

**Conclusions**

- Highest \( U_g \) before flow regime change should be used, slug flow is undesired
- Too little catalyst decreases the intrinsic reaction rate but too much decreases the mass transfer
- With the right operating conditions the 3-phase methanation achieves a high conversion at an also acceptable GHSV

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