Flexible power and synthesis plant concepts with integrated chemical power storage

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Structure

- Project HotVeGas
- Future challenges for conventional power plants
- Power-to-Gas Technology
- Analysis of IGCC-EPI concept
- Conclusion
Gasification Kinetics
- Kinetics at high temperature (1800°C) and high pressure (50 bar)
- Development of reaction models for heterogeneous char gasification

Cooling Behavior of Trace Elements
- Condensation behaviour of trace elements
- Deposition of trace elements on probes

CFD - Modeling
- Design of pyrolysis and gasification models
- Particle tracking and slag flow modeling
- Modeling of condensation of trace elements

Overall Process Evaluation
- Flexible IGCC-concepts with polygeneration and excess energy storage
- Biomass co-gasification
- Potential of future technologies
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Future development of energy system in Germany

2012

- Residual load
- Wind
- PV

2012

Load [GW]

Monday Tuesday Wednesday Thursday Friday Saturday Sunday

23% RE

80% RE

(Energy policy goal of the German government)
Future challenges for conventional power plants

2050 – Sorted annual load curve

- Decreased utilization
- Increased flexibility requirement
- Excess energy storage

Challenges:

- 33 TWh excess energy generation
- 105 TWh need of flexible production by conventional power plants
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Power to gas technology

Advantages

+ High energy density
+ Full use of the existing NG infrastructure
+ Reconversion with state of the art technology possible

Disadvantages

- High costs
- Low power-to-power efficiency
Motivation for system integration concepts

Overall efficiency of P2G:

\[ \eta_{\text{Power\rightarrow Power}} \times \eta_{\text{Electrolysis}} \times \eta_{\text{SNG}} = \frac{0.7 \times 0.95 \times 0.8 \times 0.6}{\eta_{\text{CO2}} \times \eta_{\text{SNG}} \times \eta_{\text{CC}}} = 32\% \]

Possibilities for efficiency enhancement:

- Use of the byproduct O\(_2\) of the electrolysis
- Integration of the CO/CO\(_2\) source
- Use of the heat of the exothermal synthesis
- CHP plant for reconversion of the SNG
IGCC-EPI (Excess Power Integration) concept

Features:

+ High **positive and negative flexibility** at baseload operation of the gasifier island
+ **No CO-Shift reactor and CO₂ sequestration** for adjustment of synthesis gas composition → conversion losses and investment costs can be avoided
+ **Integration of O₂** from electrolysis for gasification
+ **Integration of the heat** of the synthesis plant in the CCPP
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Methodology – Overall System Evaluation

- Literature research
  - Process schemes
  - Process parameters
  - Limitations

- Modeling of sub systems

- Verification of Subsystems

- Optimization
  - Energetic
  - Exergetic
  - Economic

- Overall system

Reference: Industrial data from a 20 MW TREMP process
Main boundary conditions of the simulation of a 125 MW<sub>th</sub> concept

Storage properties:

- SNG feed in pressure: \( p_{\text{SNG}} = 60 \) bar
- Mean O2 storage pressure: \( p_{\text{O2}} = 75 \) bar
- Specific energy consumption of the electrolyzer: \( E_{\text{S,Elektrolyse}} = 4.4 \text{ kWh/Nm}^3 \) (400 mA/cm<sup>2</sup>)

Part load behavior:

Electrolysis

- Efficiency vs. Current density [A/cm<sup>2</sup>]
- Efficiency increase

Gas turbine

- Relative efficiency [%] vs. Load fraction [%]
- Zhang (2002)
- Mean value
Overall system part-load efficiency (including reconversion of storage medias to power)

Efficiency definition:

$$\eta_{\text{Power/coal}\rightarrow\text{power}} = \frac{P_{e\text{l}(SNG)}}{\dot{m}_{SNG} \cdot H_{u,SNG} \cdot \eta_{GUD}} + \frac{P_{e\text{l}(O_2)}}{\dot{m}_{O_2} (LZ A_{Aq} + w_{s,V})} + \frac{P_{\text{Netto}}(P_{\text{Netto}} > 0)}{-P_{\text{Netto}}(P_{\text{Netto}} < 0)}$$

$$\eta_{GUD} = 60\%; \ LZ A_{Aq} = 0, 27 \text{ kWh/kg}$$
Impact of synergies on overall storage efficiency

→ Synergy effects result in an overall efficiency advantage of 6.4% points
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Conclusion

• Increased flexibility requirements for future conventional power plants

• High excess power potential and need for long-term energy storages

• Combination of power-to-gas and gasification technology results in:
  – Superior operation range of conventional power plant
  – High overall storage efficiency due to synergy effects
Thank you for your kind attention.

Questions???