Thermodynamic modelling of gas storages for optimized demand-driven operation of anaerobic digestion plants

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Development of a renewable energy system

- This needs an further increase of renewable energies (especially fluctuating RE)
- necessary are new ways to guarantee grit stability in future energy systems

Opportunity: demand driven operated biogas plants

- A more holistic control and monitoring of biogas plants is necessary
- \( \rightarrow \) Reliable gas storage filling level
Development of technical measures for improving gas management on biogas plants

- Investigation and Comparison of different storage filling level measurements
- Technical improvement of the storage filling level measurement
- Development of adapted gas extraction strategies
- Support of measurement in dead zones by model approach
- Forecast of gas storage filling levels supporting substrate management strategies

Experimental setup

DBFZ - Research biogas plant

- Temperature sensor located north approx. 15 cm inside

Fermenter volume 215 m³ with 150 m³ double membrane gas storage
Weather measurements

- Weather station (wind speed & direction, humidity, rain, pressure, temperature)
- Pyranometer (global solar radiation)

Embedded in the PLS with database

Gas storage management

overpressure relief valve

Causes of overpressure relief events

- Operation of gas holder in border area (between 80 and 100 %)
- Insufficient integration of the conversion units in plant control
- Lack of maintenance of the gas storage and conversion units
- Inappropriate feeding regimes
- No consideration of the weather conditions
**Gas storage management**

Temperature influence in the gas storage

Intraday temperature difference [°C]:
- 5.1 ↔ 29.7 = 24.6 March
- 8.4 ↔ 33.5 = 25.1 April
- 8.7 ↔ 37.7 = 29.0 April
- 11.0 ↔ 34.2 = 23.2 May
- 16.8 ↔ 42.5 = 25.7 July
- 13.2 ↔ 40.8 = 27.6 August
- 23.6 ↔ 43.4 = 19.8 September

Up to 20 % difference in capacity

Based on Mauky et al. (2017)

Demand-driven biogas production in full-scale by model predictive feed control.

Conference Proceedings of the 25th European Biomass Conference and Exhibition (EUBCE), Stockholm, Sweden, S. 1845-1851

**Influence of solar radiation on gas storage**

a) total view with normal camera modus and b, c, d): measured by Infrared camera; cross indicates the location of the respective maximal value

Source: Mauky/DBFZ
Heat Balance

Transmission heat flow from Biogas via Fermenter wall

\[ \dot{Q}_{\text{wall}} = kA_{\text{wall}} \cdot (T_{\text{biogas}} - T_{\text{Amb}}) \]

Free convection on vertical plane wall
- Characteristically length
- Correction factor
- Prandtl-number
- Grashof-number
- Nusselt-number

Forced convection
- Characteristically length
- Reynolds-number
- Prandtl-number
- Nusselt-number
- (laminar & turbulent)

Thermal conductivity values of the material with surface area and thickness

Heat transfer coefficient
GUI and Results

Calculated heat flows and temperatures

Weather data

Feed control with weather forecasts

Holistic plant control in the Projects Gazelle and OptiFlex

- Integration of influencing factors and sub-processes (e.g. Disintegration, Gas storing, conversation, mixing) in an overall plant model and control concepts

See Poster Nr. 11: Model-based Process Optimization of Biogas Plant Operation

Take Home Message

- Gas management is important, especially for advanced flexible operation
- The thermodynamic processes could be reproduced well

Current & future work

- Sensitivity analysis
- Investigations in different seasonal periods
- Including the Methods in overall plant observation and optimization
Smart Bioenergy – Innovations for a sustainable future

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