Demonstration of process integration schemes for SOEL-based Power-to-Liquid processes

Gregor Herz*, Michael Gallwitz, Paul Adam, Ralf Näke, Matthias Jahn, Erik Reichelt
Winterbergstr. 28, 01277 Dresden, Germany
*gregor.herz@ikts.fraunhofer.de

In the context of CO_2 emission mitigation carbon capture and utilization has been discussed as a technological option for CO_2-emitting processes. High-temperature electrolysis has been shown to be a promising technology for direct syngas generation in so-called Power-to-Liquid processes [1,2].

In this work, the implementation workflow for a highly integrated Power-to-Liquid process concept, utilizing Fischer-Tropsch synthesis, will be presented. Especially the implementation of heat integration and by-product utilization unique to the applied electrolysis technology will be considered. The basis for the process development was an elaborate process model, which was used to compare different process pathways for syngas production. High-temperature co-electrolysis was found to be the most efficient option due to numerous approaches for heat integration and by-product utilization [3].

In this context, the possibility to perform internal reforming of by-products within the electrolyzer to again obtain syngas can be advantageous [3]. This mode of operation has been demonstrated in electrolysis lab tests on cell and stack level, showing the ability to convert methane [4]. However, the recycled gaseous product stream from a Fischer-Tropsch synthesis is much broader in its composition and longer-chained hydrocarbons may lead to issues such as carbon formation, thermal stress and catalyst degradation. Therefore, experimental demonstration was seen as an important milestone.

Based on the model-derived data the process concept was implemented on a laboratory-scale utilizing IKTS high-temperature electrolysis stacks, a commercially relevant FT catalyst and a phase separation, where the desired products were obtained. The result was the highly integrated lab-scale plant depicted in Figure 1 which includes the possibility to recycle the tail gas into the electrolysis. It was used to study the interaction between electrolysis and FT synthesis and quantify the gain in process and carbon efficiency. An increase in carbon efficiency by a factor of three compared to the dead-end case was achieved.

Figure 1: Lab-scale integrated Power-to-Liquid plant.

Additionally, the lab-scale plant was used to validate the previously introduced process model. This allows for the model to be more broadly deployed. For one it was used to conduct a techno-economic analysis comparing low-temperature and high-temperature-based Power-to-Liquid concepts. The results have shown clear benefits of the high-temperature electrolysis, allowing for streamlined, more efficient process concepts. The validated process model will be applied within the CARE-O-SENE project, where it is deployed to investigate the effects of new FT catalyst generations on overall Power-to-Liquid process efficiency and synthetic aviation fuel productivity.

The results of the investigation emphasize the benefits of process modeling in the design process of plants, process steps and components for efficient Power-to-Liquid processes. Additionally, the advantages of high-temperature electrolysis as a highly efficient and sustainable source for syngas will be highlighted.

References

[1] D. König, R.-U. Dietrich, A. Wörner, *Europ. Congress of Chem. Engineering* (2016)
[2] G. Herz, C. Rix, E. Jacobasch, N. Müller, E. Reichelt, M. Jahn, A. Michaelis, *Appl. Energy* **292** (2021) 116655
[3] G. Cinti, A. Baldinelli, A. Di Michele, U. Desideri, A, *Appl. Energy* **162** (2016) 308-320
[4] G. Herz, N. Müller, P. Adam, S. Megel, E. Reichelt, M. Jahn, *Chem. Ing. Technik* **92** (2020) 1044-1058