ZEG Power

ZEGTech
Zero Emission Gas Power
Technology Qualification for Industrial Scale ZEG Plants

Background and objectives

Previous projects have identified the ZEG process as an especially promising method for producing hydrogen and electricity from natural gas with CO_2 capture in an efficient and cost-effective way. The process combines sorption enhanced steam methane reforming (SESMR) and high temperature solid oxide fuel cells (SOFC) for co-production of hydrogen and electricity with CO_2 capture. Fuel cells are in general a very efficient method for converting natural gas to electricity, and by utilizing the excess heat from the SOFC for production of hydrogen and total efficiency exceeding 80 % is reached, CO_2 separation and compression included.

The two key technologies (SOFC and SESMR) are tested individually in several projects and the integrated process was demonstrated as a 2 kW lab unit placed at Risavika Gas Centre's facilities (2009-2010).

One of the main challenges in SESMR is absorbents for CO_2 capture. Key factors for CO_2-absorbent materials are the total CO_2 absorption capacity, kinetics of reaction at typical SE-reforming temperatures, long term mechanical and chemical stability and low cost. Ca-based sorbents are considered to be the most promising candidates. Ca-based sorbents will in a SESMR process interact with Ni- catalysts in the reforming step. To overcome the problem of handling a mixture of two solids with different chemical and physical properties and resolve the problem related to attrition of the reforming catalyst, the integration of catalyst material within the structure of a synthetic sorbent with a high resistance to attrition would constitute a major breakthrough for the industrial development of a SE-reforming process. Development of stable "all-in-one" particles (catalyst+sorbent+support) would facilitate the fluidization properties of the solids, decrease the overall production cost of the synthetic sorbent and significantly improve the overall economy of SE reforming process system. Indeed, development of the "all-in-one" particle will reduce both reactor size and heat loss from the process, giving reduced investment cost and higher overall efficiency.

The SOFC in the ZEG concept differs from SOFC in other concepts by its high operation temperature (up to 1050^oC) and hydrogen rich fuel. By employing ceramic interconnects, the most pronounced degradation effects related to oxidation and chromium vaporisation of metallic interconnects are avoided. However, degradation due to coarsening of particles, inter diffusion of materials and de-mixing of ionic materials may increase due to the high temperature. There are not many publications of SOFCs experiments with operation exceeding a few 1000 hours. Prototech has performed long term single cell and short stack experiments up to 11 000 hours with ceramic interconnects showing only insignificant degradation. The stacks are also re-designed and changed materials for the electrodes to improve power density. It is expected that the new generation stacks will greatly enhance the performance of the ZEG power plant.

The main objective for the present project was *technology qualification of the SOFC stack and absorbents to ensure the technology basis for future industrial scale ZEG plants.* The following sub goals were defined:

- Long term testing of the new "all-in-one" particles during operation in SE reforming conditions.
- Installation of next generation SOFC with improved instrumentation for temperature measurements
- Long term operation of next generation SOFC at typical ZEG conditions.
- Characterisation of heat evolution in the SOFC
- Establish experimental data for optimisation of heat integration and system design

Obtained results

*SESMR;*The main objective of the project was to investigate the potential of a novel catalyst/sorbent hybrid material for production of hydrogen via sorption-enhanced steam methane reforming. To develop this novel hybrid material, several preparation methods were tested. The strong chemical interaction between the catalyst and the CaO fraction of the sorbent was evidenced. The key role of the pH during impregnation by aqueous media has been shown. Chemically stable “all-in-one” particles were developed and tested during 65 cycles in SE- SMR conditions, showing the potential of the method. To improve the distribution of metal within the sorbent particles and avoid the “egg-shell” distribution of the nickel, other synthesis methods were investigated and reported. Among those methods, preparation of mayenite-supported catalyst seems a promising new approach. Mixing two materials with each a stable functionality (catalyst or sorbent) supported on chemically identical support is a promising development path that should be further tested.

The obtained particles are the first reported material with combined sorbent/catalyst function with long-term chemical stability for SE-SMR application.

SOFC; The project aimed to test SOFC technologies for longer periods and evaluate the status towards the ZEG requirements. The original intention was to evaluate the ceramic SOFC in a 40 layer stack, however this stack could not give sufficient stable test results for a fair evaluation. The ceramic technology was thus evaluated with a short stack for > 2700 hours at 900^{o}C. The degradation target of < 1%/khour was just reached, however the sealing of the stack must be improved before new up-scaled stacks can be tested. Degradation rates lower than 1% /khour has also been published by other groups using metallic interconnects, but temperatures are then < 750^{o}C.

In the last part of the project it was decided to test CFY stacks from Plansee/IKTS with metallic interconnects (Cr-Fe-Y_2O_3) and with an operation temperature of 800 - 850°C. The performed tests confirm the robustness of this technology. The technology is well suited for use in industrial application, and by lowering the temperature a little below 800^{o}C, sufficient low degradation rates can be reached (at least for stacks with improved coatings). The CFY stack has also another advantage compared to the all ceramic stack; it can be operated on 97% hydrogen. System simulations have shown that by recirculating dried hydrogen, fuel with <10 % water can be obtained. This makes it possible to achieve really high efficiencies in systems that only produce electricity.

The CFY stack contains most qualities required for use in ZEG systems or other industrial systems. The degradation is still too high, but the producer has already launched a new design where they report much lower degradation. However, the operation temperature is still a limitation for use in fully integrated ZEG system with Calcium processes.

Research Partners

The present project has been carried out as cooperation between ZEG Power AS and Institute for Energy Technology (IFE) and CMR Prototech as the two main research partners.

Development of solid sorbents /”all-in-one-particles” for SE-SMR is performed at IFE. Part of the work is done in cooperation with the Telemark University College as a Master Thesis.

The SOFC development has been carried out by CMR Prototech.

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