Ribe Biogas plant in DK (Krüger©).

EFFECTIVE

Biogas – MCFC systems as a challenge for sustainable energy supply

Objectives

It is well known that Molten Carbonate Fuel Cells (MCFC) have high efficiencies. For example the efficiency of MTU's HOT MODULE is approx. 47% (AC) and close to 90%, if the thermal energy can be used, even when the module is fuelled with Biogas. MCFC's are currently (among all types of FC's) best suited for Biogas and enable electricity generation in avoidance of valueless heat, usually occurring when conventional CHP's (Combined Heat and Power Units) with an efficiency of approx. 36% (AC) are used. Since biogas is a mixture of methane and carbon dioxide it is surprising that the MCFC solely among all types of fuel cells gains an advantage of the presence of carbon dioxide. Carbon dioxide takes part in the electrochemical cell reaction and has a determining role in the formation of the electrochemical potential.

A precondition for the use of Biogas in MCFC's is the elimination of accompanying traces of detrimental gases. Therefore the RTD-work is twofold: two gas upgrading units have been developed, and the endurance of MCFC's for Biogas use must be confirmed. Major reasons why renewable energy projects fail, is the one-sided focus on technical aspects. That is why non-technical barriers shall be taken into account.

Challenges

Anaerobic digestion (AD) involves the breakdown of organic waste by bacteria in an oxygen-free environment. The biogas produced as a result is, as a renewable energy CO_2 neutral. By converting the chemical energy into electrical energy in a high temperature fuel cell, it is possible to increase the electricity output in comparison to conventional CHP).

This does not only produce less CO_2 emissions per produced kWh (in comparison with classical CHPs) but it also has been proven that using biogas as fuel is followed by a drastic decrease of regional emissions of methane.

Furthermore, MCFC's have the lowest NOx, SO_2 and VOC emission-levels compared to other conventional systems. Another feature of the high temperature fuel cell is that a part of the thermal energy, which is created in the electrochemical process, can be consumed directly at the location where it is released. This internal heat removal happens during the conversion of the methane into the electrochemical active species, hydrogen, which is an endothermal process and known as "Internal Reforming".

Until now, hardly any experience has been gained concerning the utilization of biogas in fuel cells. Innovative aspects are the development of the gas cleaning units for biogas, to remove especially H_2S, as well as endurance and performance information on MCFC – gas cleaning unit. Finally a novel technique, based on adapted Quality Function Deployment (QFD) for the holistic technology integration is used. QFD will enable the identification of optimal locations for the MCFC-Biogas plant compound in Austria, Spain and Slovakia.

The major innovative step is however the combination of MCFC's and Biogas technology. Therefore answers concerning i) the gas upgrading (reliability, costs…), ii) the endurance and performance of the MCFC system with slightly changing gas quality and composition and iii) the integration of the technology in the market have to be analysed and/or improved.

Project structure and approach

The multidisciplinary and multisectorial approach of the project and the composition of the consortium promises successful teamwork. The needed critical mass is achieved through a well balanced consortium: on the one hand a fuel cell supplier and fuel cell specialists (MTU FC and CIEMAT), gas upgraders (PROFACTOR and SEABORNE), socio-economists (STUDIA), biogas experts (UNI NITRA) and end users (URBASER & LINZ AG).

The RTD-work is twofold: Two gas cleaning units have been developed, one based on a biological and the other on a chemical principle, that reduce e.g. H_2S in Biogas from 300 ppm (=state of the art) to under 10 ppm. The expected endurance of MCFC's using Biogas as fuel is to be confirmed with two testbeds, each comprising a 300 W MCFC-lab size stack (figure 1), manufactured by MTU, and their respective gas cleaning units. One of the testbeds (mobile) is coupled with the chemical gas cleaning unit and is being tested in three different locations with different gas qualities. The second testbed (stationary) is coupled with the biological gas cleaning unit and is meant to be used for long term tests. Non-technical barriers such as economic, logistic, legal and social aspects are being assessed in Austria, Spain, Germany and Slovakia for the technology integration of the systems compound.

Figure 1: Assembly of MCFC stack at MTU premises.

Figure 2: MCFC Testbed (left MCFC unit, right controlling unit) at the Seaborne premises.

Expected impact and exploitation

The large potential for biogas coming from biogas producing facilities in both agricultural as well as industrial sectors shows a virgin area of core business for the involved sectors. The exploitation of the results is clearly focused on the promotion of the implementation of Biogas Plants using MCFC's. The gas upgrading systems are to be further developed and commercialized after the finalization of the project.

Progress to date

The work performed on the technical side of the project was the development of both the chemical as well as the biological gas cleaning units with their subsequent analytical tests. This included the setting of common interfaces between the gas cleaning units, biogas plants and the MCFC unit.

Biological gas cleaning unit: Preliminary results show that the H_2S concentration in the outlet biogas is always under 10 ppm with an inlet of approximately 400 ppm H_2S. The **chemical biogas upgrading system** has achieved together with the first MCFC test cycle also values of under 10 ppm.

Single cell tests have been performed in order to find out the impact of NH_3 on the cells. The observations were the following: (1) A slight break through of ammonia was observed. (2) The amount of ammonia, which broke through, depended on the applied load. (3) The ammonia did not cause any additional corrosion on the cell components during the operation time of about 2000 h. Additional tests should however be done in order to find explanations for the ammonia break through.

The construction of the 2 **testbeds** (figure 2) proved to be more complicated than expected, in part due to the high safety standards set by the German TÜV.

Progress to date

The first test cycle was performed at SEABORNEs location, in Owschlag, Germany. The burn-out procedure was started on this stack in April 2002 at the facilities of MTU in Ottobrunn, Germany. Then the stack was cooled down and delivered to Seaborne, where it was reactivated at the end of May. After 2,500 h operation the tests were terminated.

It is likely that the gas composition was not stable during the experimental run and the CH_4:CO_2-ratio was shifted towards higher amounts of the CO_2. Therefore the real electrical efficiency (DC) should be expected to be in the range between 35 and 52% (DC). Results on the test operation in Nitra will soon be available.

INFORMATION

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- MTU Fuel Cells (D)
- Seaborne Environmental Research Laboratory (D)
- Slovenska Polnohospodarska Universitá v Nitre (SK)
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