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Short communication

First European fuel cell installation with anaerobic digester gas in a molten carbonate fuel cell

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Abstract

The City of Ahlen in North Rhine Westphalia, Germany and RWE Fuel Cells GmbH, Essen, cooperate in order to install a molten carbonate fuel cell in the municipal sewage works of Ahlen in May/June 2005. The MCFC unit, a so-called HotModule made by MTU CFC Solutions, Ottobrunn operates on anaerobic digester gas and provides power and heat for the sewage works. This is the first project of its kind in Europe. This article outlines the experiences of RWE Fuel Cells with planning, installation and operation of MCFC systems and is focussing on the use of digester gas. The engineering and installation phase is described regarding to the special features of digester gas, for example variation in gas composition and impurities as well as different flow rates. The results of the first months of operation are interpreted and influences to the performance of the fuel cell on digester gas composition are compared. One focus of the recent RWE Fuel Cells projects is the use of MCFC systems using different biofuels. With the results from planning, installation and operation of the MCFC in Ahlen a system design for the application of different fuels can be validated and tested.

Keywords: Molten carbonate fuel cell; Fuel cell system; Anaerobic digester gas; Gas processing

1. Introduction

The target for the reduction of CO_2 emissions, as specified in the Kyoto Protocol, can only be achieved by an extended use of renewable fuels and increased energy efficiency. The energy generation from waste gases with a reasonable content of methane like anaerobic digester gas (ADG) can significantly contribute to reach this target. A further reduction of greenhouse gas emissions is possible by increasing the electrical efficiency using progressive technologies. The molten carbonate fuel cell (MCFC) is one of the most promising technologies for the energy generation in the future and is especially suited to use fuel gases with a relevant content of carbon dioxide, due to the reaction mechanisms in the cells.

2. Motivation

In the past, the City of Ahlen has operated several reciprocating gas engines for the combined generation of power and heat (cogeneration) from anaerobic digester gas. Due to poor electrical efficiency, high maintenance cost and local emissions of noise and exhaust, it was decided to look for alternatives.

The installation of an MCFC unit has the following advantages compared to conventional gas engine technology:

- high electrical efficiency, increasing the electrical power output from a given quantity of anaerobic digester gas;
- high temperature level of the recoverable heat, suitable for hot water production as well as for sludge drying, in case of stricter sludge treatment regulations in the future;
- lowest exhaust gas emissions;
- low maintenance requirements.

The project was initiated by the City of Ahlen and jointly developed together with RWE Fuel Cells, Essen. Project costs are shared between the project partners City of Ahlen, RWE Fuel

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Cells and MTU/DaimlerChrysler, and the project is also funded by the federal state of North Rhine Westphalia.

3. Project partners

The City of Ahlen and RWE Fuel Cells cooperate in order to install a HotModule in the municipal waste water treatment plant of Ahlen in May/June 2005. The HotModule operates on anaerobic digester gas (ADG) and supplies electricity and heat to the waste water treatment plant. This is the first project of its kind in Europe.

The City of Ahlen is located in the German federal state North Rhine Westphalia, on the northern borderline of the industrial Ruhr area. It has developed itself to a local economic centre for small and medium-sized businesses, with some 55,000 inhabitants in an area of about 12,300 ha.

RWE Fuel Cells GmbH, Essen is a wholly owned subsidiary of the RWE AG, Essen, and works on the development and marketing of products and services based on fuel cells as well as other small distributed energy plants, such as micro-gas turbines and Stirling engines. RWE Fuel Cells exclusively focuses on stationary fuel cells for commercial, industrial and private uses. In 2003, RWE Fuel Cells and MTU Friedrichshafen established a Joint Venture. The joint company is the MTU CFC Solutions GmbH, Ottobrunn (Munich) and manufactures the so-called HotModule, a 250 kW molten carbonate fuel cell (MCFC). MTU CFC Solutions has launched several demonstrations of carbonate fuel cell systems and intends to achieve a leading market position in the field of high-temperature fuel cells (Fig. 1).

4. Waste water treatment plant in Ahlen

The installation site for the HotModule is the waste water treatment plant of Ahlen. Having a capacity of 130,000 population equivalents, the waste water treatment plant in Ahlen cleans waste water from some 55,000 people living in Ahlen as well as from local industry.

Similar to most German municipal waste water treatment plants, water cleaning in Ahlen is achieved by a mechanical and a biological treatment stage. The mechanical treatment stage starts with rakes and grids that hold back garbage floating in the waste water stream. It continues with a sand trap, where sand and grit are removed, and is followed by the primary treatment basins. Here, the flow velocity of the waste water stream is greatly slowed down, allowing dispersed particles to settle down on the bottom of the basins. This so-called primary sludge is collected and fed into the sludge treatment.

Fig. 1. Fuel cell building in Ahlen.

In the biological treatment stage, suspended solids, dissolved organic as well as inorganic substances are removed from the waste water by various micro-organisms. The waste water passes through anaerobic as well as aerobic zones, and nitrates and phosphates are consumed in that process. Flakes of sludge are growing, which are made up of colonies of micro-organisms. Later, these flakes settle at the bottom of the circular tanks in the final clarification stage. Some of this secondary sludge is recycled into the biological treatment stage to speed up new micro-organism growth, and the surplus sludge is fed into the sludge treatment.

The sludge treatment includes dewatering using centrifuges and fermentation in anaerobic digester tanks. At a temperature of 38 °C, methane bacteria decompose the organic matter in the sludge and release methane and carbon dioxide in that process—anaerobic digester gas (ADG).

The waste water treatment plant in Ahlen produces about 1500–2000 m^3 ADG per day. Based on an average methane content of about 60%, this contains enough energy to operate an MCFC unit of the 250 kW class near full load.

5. Project development and engineering

Main engineering task in this project was to find technical solutions to integrate the MCFC unit into the existing infrastructure of the waste water treatment plant, and to match ADG conditions with the requirements of the HotModule.

Development and engineering work by RWE Fuel Cells include:

- design and plant layout of the MCFC unit and auxiliaries (fuel cell system);
- detailed analysis of ADG gas compounds, trace elements and humidity for the selection/design of a suitable gas processing unit;
- selection/design of a monitoring system for the gas processing unit cleaning performance, for protection of the MCFC unit;
- gas compressor selection to adapt the gas pressure according to the requirements of the HotModule and the gas processing unit;
- development of a control strategy for Natural Gas/ADG switching during normal fuel cell operation;
- communication between the all technical systems, transmission of data and operation signals;
- prevent shut downs of the MCFC unit due to failures in the complete system;
- modifications in the waste water treatment process and gas production;
- hazard analysis and certification (CE) of the complete fuel cell system.

The produced ADG typically contains 38% CO_2. The lower heating value compared to natural gas requires a gas volume flow that is about 50% higher at maximum load. Due to the higher flow resistance, a higher inlet pressure at the power plant interface is required.

A gas processing unit with an absorption and adsorption stage was selected to remove contaminants and humidity from the ADG stream.

To increase the fuel gas pressure, an oil-cooled gas compressor was chosen that is suitable for both ADG and natural gas. Oil-free gas compressors are more expensive and often less efficient; however, in case of an oil-cooled compressor special care must be taken to guarantee the necessary gas quality for the fuel cell.

To protect the HotModule against high oxygen concentration in the ADG, three safety strategies have been implemented into the plant design:

- ensure overpressure in the entire ADG system, from the storage tank to the MCFC unit (redundant pressure sensors, set to >10 mbar g);
- continuous monitoring of the oxygen concentration after the fuel gas compressor;
- integration of a pre-oxidizer catalyst into the gas conditioning section of the MCFC unit.

To allow a constant operation of the fuel cell in case of failure of the ADG supply, switching from ADG to natural gas is provided. A continuous gas analysis system senses the actual heating value or methane content of the supplied fuel gas and provides an input signal to the fuel cell controller, which is especially important when switching between ADG and natural gas. The gas analysis system also monitors the oxygen content for safety reasons, and it ensures that the ADG is not contaminated by detecting the H_2S concentration in the cleaned gas.

For a scheme of the complete fuel cell system (see Fig. 2).

6. Time schedule

Beginning of planning and design	July 2004
Ordering of main components	End of 2004
Site planning complete, main components ready for delivery	End of March 2005
Assembly of HotModule and auxiliary equipment	April–May 2005
Start up of fuel cell system	June 2005
Acceptance by the City of Ahlen	July 2005

7. Start up procedures and trial operation

The HotModule was heated up to its operating temperature of more than 600 °C. At this temperature, the carbonate in the cells is in the molten state and ready for the electrochemical fuel cell reaction.

As soon as the fuel cell system was operational, two acceptance tests were performed:

- For NG: continuous run for 5 days at an electrical load of >100 kW to the grid, including 8 h with more than 200 kW load to the grid.
- For ADG: continuous run for 5 days at an electrical load of >100 kW to the grid, including 8 h with more than 150 kW load to the grid.

Trials of switching from ADG to NG and reverse were successfully completed, but revealed that some minor technical modifications and some new controller settings were necessary (Fig. 3).

The site acceptance tests were successful, and the fuel cell system was accepted and transferred to City of Ahlen. During the site acceptance tests, the projected power levels for both NG and ADG were surpassed.

Ongoing testing is under way to determine the MCFC power plant's limits in terms of power output and efficiency. In the

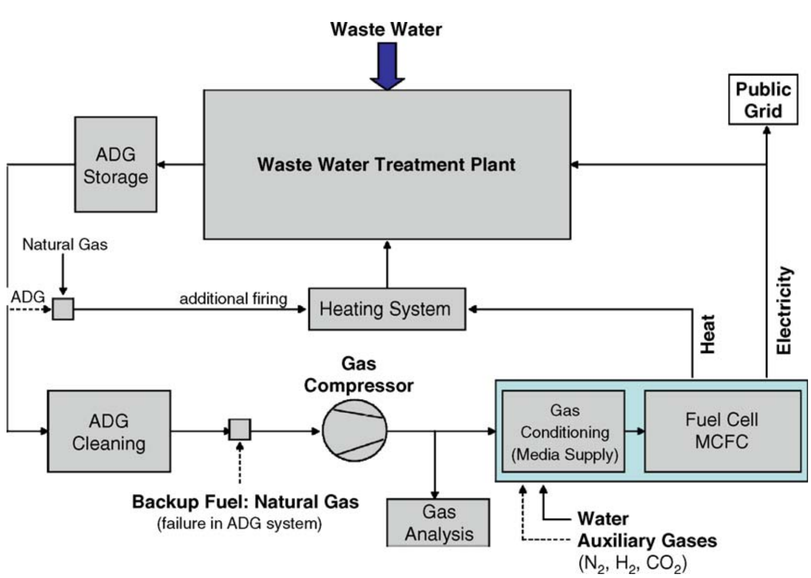

Fig. 2. Complete fuel cell system.

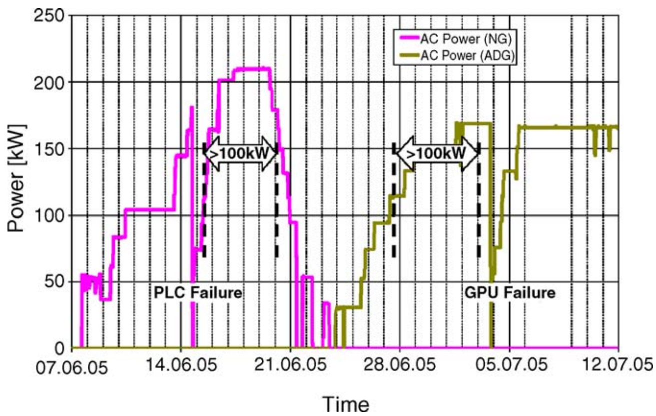

Fig. 3. Trial operation on natural gas and ADG.

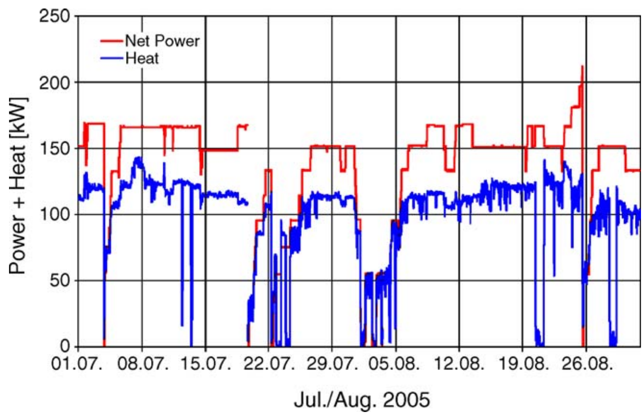

Fig. 4. MCFC power output and heat recovery.

first month of operation, only two failures of energy generation with disconnection the grid occurred, one failure due to a bad connection in the programmable logic controller, and another failure when changing a filter in the gas processing unit. After both failures, the fuel cell system was restarted immediately, so the availability was close to 100%. Between the acceptance tests for NG and ADG the fuel cell system was stopped to complete some outstanding installation work (Figs. 4 and 5).

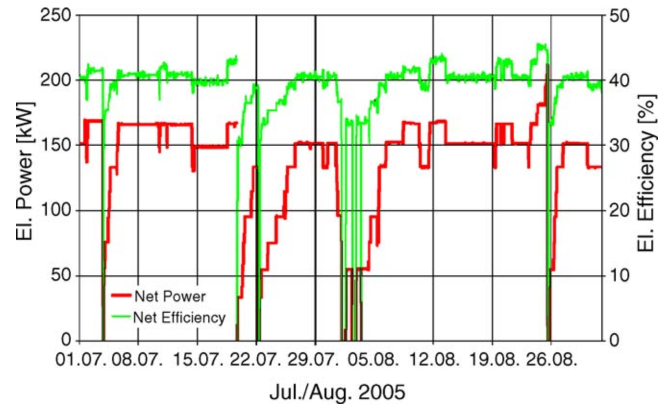

Fig. 5. MCFC electrical power and efficiency.

The fuel cell system is operated by the personnel of the waste water treatment plant. RWE Fuel Cells supports the site operators via remote control of the fuel cell system and offers an on-call duty by qualified engineers during the first 3 months.

8. Outlook

RWE Fuel Cells will design and install the next fuel cell system in Leonberg, Germany by the end of 2005. The new fuel cell project will convert biogas from biowaste into clean energy. The experiences gained during the ongoing operation of the MCFC on ADG fuel will provide a valuable feedback for the design and engineering of the Leonberg Project as well as other installations in the future.