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Short communication

Large stationary fuel cell systems: Status and dynamic requirements

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Abstract

Molten carbonate fuel cell demonstrations to-date, have been able to show the highest fuel-to-electricity conversion efficiencies (>50%) of any stand-alone fuel cell type.

The primary developer of this type of fuel cell in United States is Fuel Cell Energy Corporation (FCE), the developer and manufacturer of the Direct FuelCell™ concept. FCE and MTU CFC Solutions in Germany, a licensee of FCE have demonstrated carbonate fuel cells from 10 kW to 2 MW of electrical output on a variety of fuels. IHI in Japan are also developing carbonate fuel cells for stationary power and have recently successfully demonstrated the technology in Kawagoe, Japan. In Italy, Ansaldo fuel cell have demonstrated a 100 kW carbonate fuel cell in Milan. In Korea, the Ministry of Commerce, Industry and Energy has committed to install 300 fuel cell units, sized 250 kW to 1 MW, for distributed power generation by 2012.

Carbonate fuel cell technology is more fuel flexible than lower temperature fuel cell technologies and is well suited for on-site stationary CHP applications as well as to marine, military, and traction applications.

The present paper gives an overview about the commercialisation efforts for the molten carbonate fuel cell technology.

Keywords: Molten carbonate fuel cells; Commercialisation; Field tests

1. Introduction

Increasing demand for reliable power worldwide, supplemented by air pollution concerns caused by older, combustion power generation, and unreliable electrical grid delivery systems present significant market opportunities for distributed generation products. Fuel cell power plants electrochemically produce electricity directly from readily available hydrocarbon fuels, such as natural gas and waste-water treatment gas. Especially high temperature fuel cells offer significant advantages compared to other power generation technologies, including:

- High fuel efficiency;
- Ultra-clean emissions;
- Improved reliability;
- Quiet operation;
- Flexible siting and permitting requirements;
- Scalability;
- Ability to provide electricity and heat for cogeneration applications, such as district heating, process steam, hot water and absorption chilling for air conditioning;
- Potentially lower operating, maintenance and generation costs than alternative distributed power generation technologies;
- Since fuel cell power plants produce hydrogen from readily available fuels such as natural gas and waste-water treatment gas, they can be used to cost-effectively co-generate hydrogen as well as electricity and heat.

The carbonate fuel cell, often referred to as the molten carbonate fuel cell (MCFC), is one of the fuel cell technologies that has proven efficiency and environmental performance. In addition, significant reductions in carbonate fuel cell capital cost are expected in the next few years. In particular, the use of carbonate fuel cells in the distributed power market could offer an ideal solution to increased energy demands with concurrent expectations for reliability and environmental sensitivity. The carbonate fuel cell concept involves conduction of carbonate ions ($CO_3^{=}$) within an immobilized mixture of molten carbonate salts. Other cell components are based on nickel and stainless steels, which contribute to initial capital cost, but, are significantly less expensive than the precious metal catalysts used in lower temperature fuel cells.

Since the charge carrier is an oxidant, several fuel species can be oxidized within the anode compartment leading to inherently greater fuel flexibility. To-date, carbonate fuel cells have been

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operated on hydrogen, carbon monoxide, natural gas, propane, landfill gas, marine diesel, and simulated coal gasification products.

The typical operating temperature of a carbonate fuel cell is around 650 °C. This temperature is almost ideal from the system perspective, since it allows higher Nernst potential compared to SOFC operating at around 800–1000 °C (ideal Nernst potential increases with decreasing temperature) while still providing high temperature thermal energy sufficient to sustain and support reformation chemistry. Thus, carbonate fuel cell system designs typically contain an internal reformer.

The high temperature thermal effluent of a carbonate fuel cell allows significant cogeneration and/or integration with a heat engine cycle, typically called a "hybrid". Several carbonate fuel cell hybrid systems with fuel-to-electricity efficiencies greater than 70% have been conceptualized with some under development today. The system currently in development by Fuel Cell Energy and Capstone Turbine in Danbury, Connecticut is the prime example.

The high efficiency, low emissions, and fuel flexibility features of carbonate fuel cells together with recent demonstrations of robust and reliable operation, and the potential for dramatic cost reductions make carbonate fuel cells a key emerging technology for meeting future energy demands.

2. MCFC development and commercialization in Asia

Two countries in Asia are involved in the development and commercialisation of molten carbonate fuel cells, namely Japan and Korea.

Development of MCFC in Japan was started as a "Moonlight Programme" by the Agency of Industrial Science and Technology of the former Ministry of International Trade and Industry (MITI) in 1981. It was then taken over by a "New Sunshine Programme" of MITI and a Phase III Program started as a 5-year program in 2000.

As a highlight of the "New Sunshine Programme" two companies, Hitachi and Ishikawajima-Harima Heavy Industry (IHI), were strongly involved in developing and building a 1000 kW MCFC power plant. The plant was erected in Kawagoe and each company supplied 500 kW stack capacity. IHI was additionally in charge of the overall design and the control system of the plant. The test was executed successfully in 1999/2000 over 5000 h, the first time that a MCFC MW-System was operated under pressurized conditions.

Based on the experience gained with the MCFC test plant operation, development of MCFC systems has entered a new stage to supply the emerging market for MCFC plants in the Phase III Program. The NEDO target is now the development of a "Pressurized Compact Power Generation System". In a first step, a 300 kW class pressurized generation system was developed (Fig. 1). The characteristic of the system are the combination of a MCFC with a gas turbine to form a hybrid system, external reforming and pressurized operation. To commercialize the system it was planned to introduce it first in several hundred kW and several MW distributed cogeneration systems.

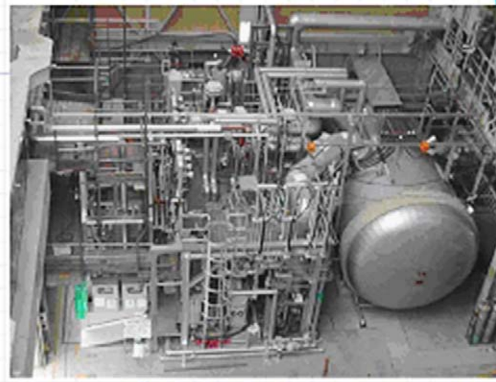

Fig. 1. A 300 kW compact system in Kawagoe.

A further plan foresees the development of a 7 MW power plant for large-scale cogeneration systems. This plant will be equipped with 8 modules with two 250-cell stacks each and a reformer in a pressure vessel and a gas turbine operated at 1.1 MPa. The designed gross output is 7.1 MW that will be generated by the stack and the gas turbine with 5.8 and 1.3 MW, respectively. The designed net output is 6.8 MW and net efficiency is 57% (LHV). This system has an anode gas recycle with an adiabatic reformer to improve the reforming ratio caused by higher pressurized operation.

To design the higher pressurized system, it is need to have evidence that the system can be operated stably in pressurized condition at 1.1 MPa. The Phase III Program has a plan to estimate the stability and performance of the module in the pressurized condition.

In Korea, the Molten Carbonate Fuel Cell is regarded as a technology with high potential in future electric power generation market by its own outstanding characteristic [1]. Recognizing this high potential, the Korean Electric Power Research Institute (KEPRI) started the first phase MCFC system development program in 1993 and successfully completed this phase by developing a 2 kW stack by 1996. The second phase of the program aiming at a 100 kW system development has been carried out since 1997. As an interim target prior to the 100 kW system development, a 25 kW MCFC system was built and tested to verify scale-up technology (Fig. 2).

On the basis of the experience of 25 kW system operation, the design of a 100 kW system has been executed. Along with the system development, the fabrication process of cell components has been optimized, too. A 250 kW packaged prototype will be developed by 2008 if the 100 kW system test proofs to be successful. KEPRI has a plan of introducing a 250 kW-class MCFC plant as a distributed source to the market in 2010.

3. MCFC development and commercialization in USA

Fuel Cell Energy, Inc. Danbury, Conn., is a world-recognized leader for the development and commercialization of a high effi-