Photo-rendered impression of packaged 20kW SOFC system with footprint 1.6 x 0.8 m^2.

Compact, low-cost power plant based on planar SOFC

PROCON

Objectives

Solid Oxide Fuel Cells (SOFC) offer the highest electrical efficiencies of all the fuel cell types when operating on natural gas so they could play an important role in reducing CO_2 emissions. To be commercially attractive, SOFC systems must be designed to reduce plant size and complexity and minimise the cost and numbers of components that make up the complete balance-of-plant. Realising these low-cost concepts requires an integrated approach to SOFC stack and system development.

Currently the main cost component of a SOFC system is the stack. Planar stack geometries offer high power densities and potentially low manufacturing costs, which can be further reduced if the operating temperature can be lowered sufficiently to allow the use of stainless steels in their construction. The objective of this project was to test the feasibility and performance of a novel, planar SOFC stack operating at reduced temperature and to investigate its integration into a compact and low-cost power plant design.

Challenges/Problems addressed

There remain several important technical hurdles to be solved, but the key to the future commercial success of SOFC systems will be their cost. SOFCs based on planar cells offer the potential for high power densities and cost-effective manufacturing. A significant boost to the reduction in cost of planar SOFC would be achieved if readily available and easily formed metals, such as ferritic stainless steels, could be used for the interconnect plate and gas manifolding. However, the problems of high temperature corrosion mean this is only realistic if the stack operating temperature is reduced to temperatures below around 800°C.

One route to achieve this temperature reduction is to use anode-supported-cells. Conventionally, planar cells use the electrolyte to support thin electrodes on either face. This limits minimum electrolyte thickness to around 150 μm. By using a thick, structural anode, much thinner electrolytes can be used with a concomitant reduction in cell resistance. Work at Forschungszentrum Jülich, as well as elsewhere, indicates that anode-supported cells will enable stack-operating temperatures around 750°C compared to the 900°C necessary for electrolyte-supported, planar cells. As well as lower stack costs, reduced temperature stack operation should also allow a reduction in balance-of-plant costs, by enabling lower cost components, such as heat exchangers, fans and compressors, to be specified.

To exploit the real benefits of planar SOFC stacks, they must be integrated into compact, low-cost systems offering high overall efficiencies. This requires the investigation of innovative system cycles and the specific design of components in order to achieve the necessary level of integration.

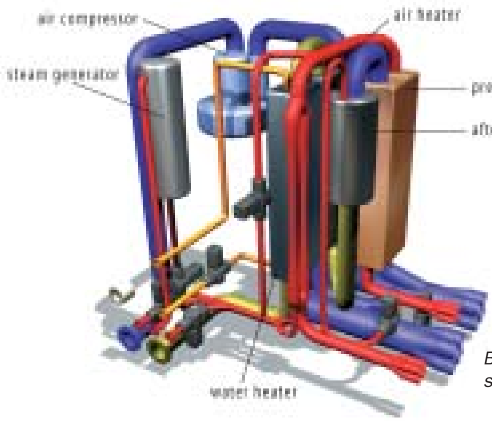
Project structure

The project consortium consisted of ALSTOM Research and Technology Centre (ART, part of the ALSTOM T&D Sector), Forschungszentrum Jülich (FZJ) and Prototech AS. Based on the target of a compact, efficient 20 kW SOFC system, the partners derived and modelled plant concepts that would meet the initial specification for the unit. The selected design and flow sheet data provided the basis for the ongoing system design and analysis. In parallel, an SOFC stack module based on an anode-supported cells concept was developed in preparation for a proof-of-concept test at the 5 kW-scale. As well as project co-ordination, the role of ART was to develop a dynamic model of the SOFC system for control and operability studies and to investigate the design of the DC/AC converter. Prototech's responsibility was the conceptual design of the 20 kW system and to perform the detailed engineering of key system components, namely the natural gas reformer and recycle ejectors. The role of FZJ was to investigate the design of the 20 kW SOFC module, comprising 4 X 5 kW stacks. In parallel, FZJ performed the detailed engineering of the 5 kW stack and produced the fully instrumented rig for the subsequent test.

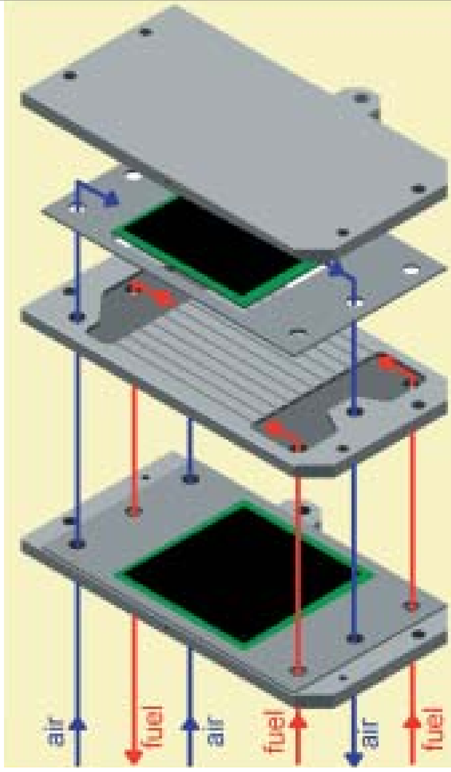
The project was supported by the ongoing programme of development at FZJ on an SOFC stack based on anode-supported cells, including work on the BMWi-project, Zellen und Stacks (ZEUS).

Expected impact and exploitation

With predicted electrical conversion efficiencies above 50%, SOFC systems should be significantly more efficient than conventional generating technologies. SOFC plant is therefore expected to make more efficient use of fossil fuels and cut emissions of CO_2. Other emissions of pollutants



Balance-of-plant layout for 20 kW system design.



Schematic of E-design stack based on 20 cm x 20 cm anode-supported cells, with internal manifold.

(UHC, SO_x, NO_x and CO) should also be at least an order of magnitude lower than those from combustion-based generators.

The ongoing deregulation of electricity markets is being accompanied by a move from centrally generated electricity towards distributed energy resources (DER). This movement offers the consumer a number of potential advantages including reduced energy costs and security of supply. SOFC systems should be ideally suited to the distributed generation market with their high efficiency at full and part-load. There is also the opportunity to use the high grade exhaust heat in co- or tri-generation mode.

The technology is still several years from commercialisation, but the successful results from this project contribute to the growing European Research Area in SOFC and establish the EU as a leading player in this emerging technology.

Results

A conceptual 20 kW SOFC system has been designed based on a specification for a grid-connected generator that is compact and potentially low-cost. Novel recycle loops for the anode and cathode exhaust gases have been included which ensure high system efficiency and reduce the system size. A detailed dynamic model of the system has been developed which includes simulated control loops, which demonstrate the robust and controllable operation of the system at full and part-load, as well as start-up from cold and safe shutdown.

Detailed engineering of key components of the conceptual 20 kW system has also been performed. This includes a novel, natural gas pre-reformer; ejectors for exhaust gas recycling and the power conditioning system that will enable connection of the system to the grid.

In parallel with the system development, an innovative SOFC stack module has been designed and its performance modelled. The stack module is based on a planar SOFC stack using anode-supported cells, which is designed for operation at temperatures below 800ºC. A fully instrumented test facility has been designed, built and commissioned. To date, performance of a 40-cell stack giving outputs up to 5.4 kW on reformed methane has been demonstrated.

The project results demonstrate that cost-effective and very compact SOFC systems can be developed that are based on intermediate temperature SOFC stack technology. Further work must continue to address issues of stack reliability and lifetime as well as cost reduction through design and manufacturing scale-up.

INFORMATION

References: ENK5-CT-1999-00026

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- ALSTOM Research and Technology Centre (UK)
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- Prototech (NO)

Contact point:
Andrew Hyde
Tel: +44-1785-27-46-65
andrew.hyde@tde.alstom.com

EC Scientific Officer:
Antonio Paparella
Tel: +32-2-2957240
Fax: +32-2-2964288
antonio.paparella@cec.eu.int

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