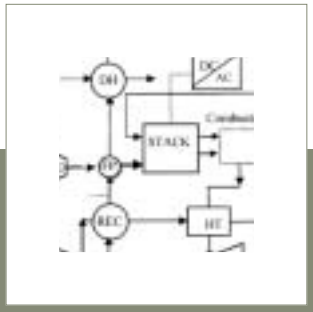

Integrated modelling study of FC/GT hybrids

IM-SOFC-GT

Objectives

Fuel Cell/Gas Turbine (FC/GT) hybrid systems can dramatically improve both local and global environmental impact of power generation. This is achieved through their near-zero emissions of NO_x, SO_x, CO and particulates, low noise characteristics and their potential to generate electricity at efficiencies above that of large conventional generation plants.

The main objective of the project is to develop the capability to assess the performance of FC/GT hybrids using a close integration of system and stack models and set performance requirements for FC/GT hybrid based generation systems through a technology characterisation. A wide range of system configurations is explored to find solutions with a balance of system efficiency, low emissions and low cost.

Challenges

The project focuses on stationary power generation systems primarily fuelled with natural gas. Three types of sub-systems are considered for atmospheric and pressurized configurations: sub-MWe high efficiency distributed generation systems, 1-3MWe systems suitable for CHP schemes and 20-30MWe power systems. The development of different complex cell models is necessary to perform the integration between cell and conventional hybrid system components. Thus, generic and detailed (finite volume) cell models are adapted to Rolls-Royce FC technology and they require proper validation against experimental data.

The system modelling work focuses on cell model integration, turbo-machinery, heat exchangers and other components. Co-operation between gas turbine manufacturers, utility companies and modellers has been essential to bring a wide range of on- and off-design data for the three power size ranges.

Finally, the project assesses how market pressures map into product requirements.

Project structure

The project consortium consists of 10 partners from four different EU countries plus Switzerland. Two Universities: Genova and Lund; one FC stack manufacturer Rolls-Royce Fuel Cell Systems; two utility companies: ENEL Produzione Spa and Sydkraft AB; four GT manufacturers: Turbomeca SA, ABB Turbo Systems Ltd, Alstom Power Sweden AB and Turbec AB; and one consulting company: PA Consulting Group.

The project is centred on four main activities: stack modelling capability, system modelling capability, system concept design and performance requirement.

The performance requirement activity analyses all of the economic, commercial, operational and environmental data/methods, helps characterize the technology and defines the performance requirements of future FC/GT hybrids. The stack modelling capability activity adopts a progressive approach to develop and validate a tool for stack modelling. The system modelling activity develops a tool for both on and off-design performance of integrated systems based on FC/GT hybrids. The system concept design activity generates preliminary systems designs to meet market requirements provided by the performance requirement activity.

The project has required a very close co-operation between these four activities to deliver useful results.

Expected impact

This represents the first overall system design of SOFC/GT hybrids performed in cross-European co-operation between manufacturers of both FC and GT, universities and end-users.

The latest technology of hybrid concepts is applied to the design of FC systems intended as commercial products. The models are validated using experimental data from the Rolls-Royce Integrated Planar SOFC stacks. Detailed market information is used in combination with the latest stack and component technologies to steer system development towards commercially attractive SOFC/GT hybrid designs.

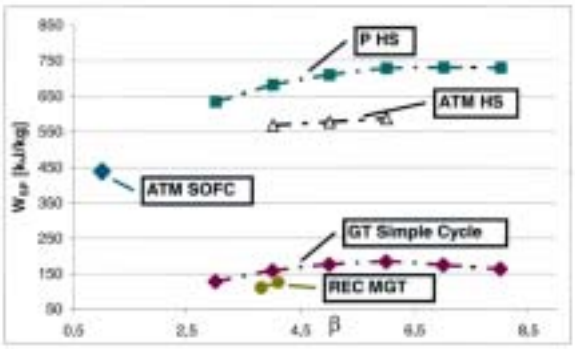

Figure 1: Systems comparison; Specific Power (W_{sp}) vs Pressure ratio ß.

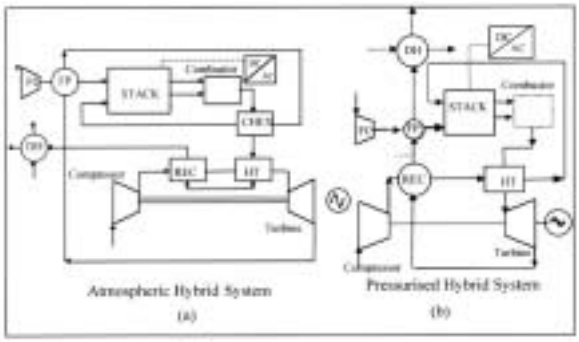

Figure 2: System Layout.

The suppliers of energy system components, end-users and universities will gain an improved understanding of the technology and economy of FC/GT hybrid based power generation systems. Importantly, it will be possible to formally express strategic objectives to develop such hybrid systems and the three main sub-systems identified in this project: sub-MWe, 1-3MWe and 20-30MWe.
This project will increase the competitiveness of European clean SOFC technology and accelerate the market introduction of the FC/GT hybrids.

Results

The project will be completed by the end of July 2003.
A first result has been obtained by comparing pressurized hybrid systems (P-HS) with atmospheric hybrid systems (ATM-H) and other power plants, see Figure 1 showing specific power [kWe/$(kg/s)_{air}$] versus pressure ratio b. The main characteristic of P-HS is their higher specific power than the other systems. This is mainly due to the very high efficiency of the pressurised fuel cells. Also, the high value of specific work denotes a more compact hybrid system design.
A second set of results has been obtained from a more detailed comparison between P-HS and ATM-HS in the 1-2MWe power size range. The layouts of the complete plants (atmospheric and pressurised) are shown in Figure 2 (a) and (b).
First, P-HS have less critical components than atmospheric plants. The main constraints are related to the compatibility between the characteristics of the exhaust gases of the Fuel Cell stack and the flow properties required for the turbine. In particular, the water content in the expanding flow is higher than the typical value for standard turbo-machinery. This has already been addressed with steam injection or humid cycle. In addition, the turbine inlet temperature must agree with the technological limit for small sized un-cooled gas turbines (about 900-950°C).
Second, the efficiency of the pressurised system is more than 10% higher than the atmospheric one.
Finally, the ATM-HS has more stringent technological constraints related to the high temperature heat exchanger design. The heat exchanger will require high cost material and manufacture processes.

In conclusion, the main result of this work is the evident superiority of the pressurised configuration versus atmospheric, in terms of efficiency, specific power and cost of electricity.

INFORMATION

References: ENK5-CT-2000-00302

Programme:
FP5 - Energy, Environment and Sustainable Development

Title:
Integrated Modelling Study of FC/GT Hybrids (IM-SOFC-GT)

Duration: 30 months

Partners:
- Rolls-Royce (UK)
- Turbec (S)
- ABB Turbosystems (CH)
- Turbomeca (F)
- Sydkraft (S)
- University of Genova (I)
- University of Lund (S)
- Alstom Power (S)
- ENEL Produzione (I)
- PA Consulting Group (F)

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Status: Ongoing