HYBRID FUEL CELL / GAS TURBINE SYSTEMS

HYBRID – 220KW SOFC/MICRO TURBINE GENERATOR SYSTEM

System Configuration

Stack:· Siemens Westinghouse tubular SOFC
- 100 kW stack at atmospheric pressure
- Pressurized to 3 ATM to produce 180 kW
- 1152 cells, 1.5 meters in height
- Operates at 1000 °C
- Air inlet temperature is 500 °C (preheated)
- Air outlet temperature is 800 °C (goes to MTG)

Microturbine Generator· Ingersol Rand (Originally NREC MTG)
- Size is 70 kW (oversized) - only 20-30 kW produced in this configuration
- Dual shaft microturbine
- High pressure turbine drives compressor
- Low pressure turbine drives AC generator

Fuel
- Natural gas at supplied at 100 psi pressure
- Pre-reformers located in the stack to generate H2 from natural gas

Overview

The world's first Solid Oxide Fuel Cell (SOFC) / gas turbine hybrid system was delivered to the National Fuel Cell Research Center in June of 2000 for operation and testing on behalf of Southern California Edison and in cooperation with Siemens Westinghouse Power Corporation.
The hybrid system includes a pressurized Siemens Westinghouse SOFC module integrated with a microturbine / generator supplied by Ingersoll-Rand Energy Systems (formerly Northern Research and Engineering Corp.)

The system has a total output of 220 kW, with an output of approximately 180 kW from the SOFC and approximately 40 kW from the microturbine generator.

This system is the first-ever demonstration of the SOFC/gas turbine hybrid concept. This proof of concept demonstration has already demonstrated the high efficiency feature of hybrid systems with a world record fuel-to-electricity conversion efficiency of approximately 53% for this size class.

The system continues to undergo testing at the NFCRC to determine its operating characteristics and operating parameters, and gain experience for the design of prototypes and commercial products. Eventually, such SOFC/GT hybrids should be capable of fuel-to-electricity conversion efficiencies of 60-70%.

If a SOFC is pressurized, an increased voltage results, leading to improved performance. For example, operation at 3 atmospheres increases the power output by approximately 10%. However, this improved performance alone may not justify the energy required for pressurization. What will justify the expense of pressurization is the ability to integrate the SOFC with a gas turbine that needs a hot pressurized gas flow to operate. Since the SOFC stack operates at 1000°C it produces a high temperature exhaust gas. If operated at elevated pressure the exhaust becomes a hot pressurized gas flow that can be used to drive a turbine. If an SOFC and a gas turbine are integrated carefully, the pressurized air needed by the SOFC can be provided by the gas turbine's compressor, the SOFC can act as the system combustor, and the exhaust from the SOFC can drive the compressor and a separate generator. This yields a dry (no steam) hybrid cycle power system of unprecedented electrical generation efficiency.

Objectives

The $16 million Energy Department's contract, which is managed by its National Energy Technology Laboratory, calls for a total test program of at least 3000 hours to meet the following objectives:
- Multi hour demonstration,
- Identification of design and development issues,
- First experimental data set for hybrid system,
- Gain insight into hybrid systems,
- Acquire data for model validation and insight, and
- Facilitate Market

Status

As of Summer 2002, the system has been tested over four separate periods of time for an excess of 1,500 hours. It is expected that the system will be restarted in the fall of 2002.

April 2000 - Factory Acceptance Test in Pittsburgh (4/1/00 - 4/8/00) 200 hours

June 2000 - Delivered to NFCRC

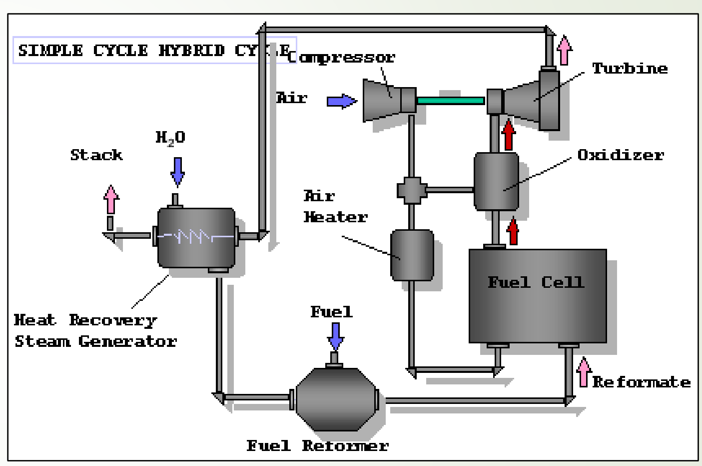
June 2000 - 1st Start: (6/3/00 - 6/11/00)
- Early test data show fuel to electrical efficiencies of approximately 53%, believed to be a world record for the operation of any fuel cell system on natural gas.
- Improvements in the technology could ultimately raise efficiencies to 60% for smaller systems and 70% or higher for larger systems.

January 2001 - 2nd Start: (1/8/01 - 2/11/01)

January 2002 - 3rd Start: (1/31/02 4/7/02)

How it works

During normal operation air enters the compressor and is compressed to ~3 atmospheres. This compressed air passes through the recuperator where it is preheated and then enters the SOFC. Pressurized fuel from the fuel pump also enters the SOFC and the electrochemical reactions takes place along the cells. The hot pressurized exhaust leaves the SOFC and goes directly to the expander section of the gas turbine, which drives both the compressor and the generator. The gases from the expander pass into the recuperator and then are exhausted. At ~400F the exhaust is hot enough to make hot water.
Electric power is thus generated by the SOFC (DC) and the gas turbine generator (AC) using the same fuel/air flow. Analysis indicates that with such SOFC/GT hybrids an electrical efficiency of 58% can be achieved at power plant capacities as low as 250 kW, and 60% as low as 1 MW using simple small gas turbines. At the 2 to 3 MW capacity level with larger, more sophisticated gas turbines analysis indicates that electrical efficiencies of 70% or more are possible.



Personnel

Student(s): Tom Smith (Grad)
Faculty: Prof. Scott Samuelsen
Staff: Dr. Jacob Brouwer

National Fuel Cell Research Center
www.nfcrc.uci.edu

Project Sponsors:
•Southern California Edison
•Siemens Westinghouse Power Corporation
•U.S. Department of Energy
•California Energy Commission
•Electric Power Research Institute (EPRI)
•South Coast Air Quality Management District