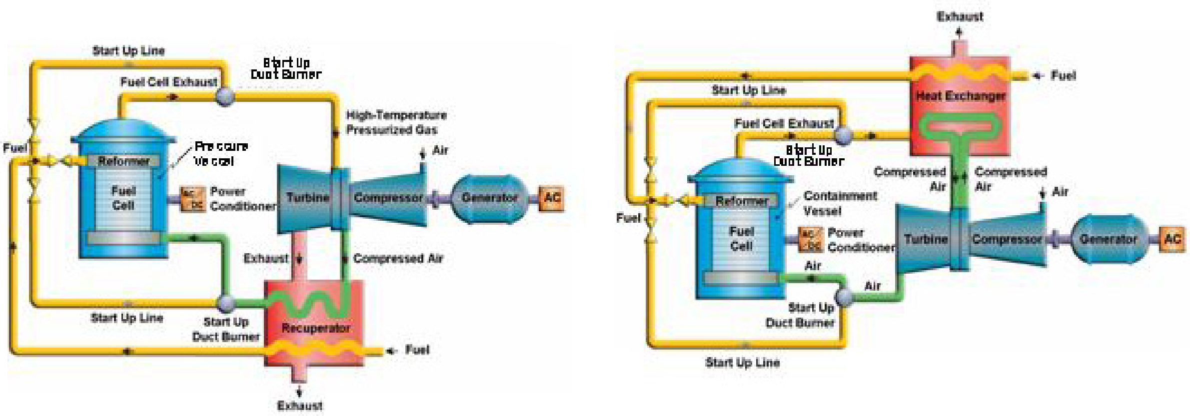
2.1.3 HIGH-EFFICIENCY GAS FUEL CELL/HYBRID POWER SYSTEMS

Technology Description

Fuel Cell Hybrid Cycles



Direct Fuel Cell Turbine Cycle

Indirect Fuel Cell Turbine Cycle

The ultimate goal of this technology is to develop systems that use natural gas or hydrogen (from coal, natural gas, or other sources) for highly efficient power generation. This also includes standalone applications of small to medium gas turbine systems, as well as advanced turbine systems for cogeneration application. Near-zero CO_2 emissions could be achieved with the integration of CO_2 capture.

System Concepts

- Hybrid systems that combine fuel cells and gas turbines to create a high-efficiency power module with near-zero emissions for central power or grid support applications.
- High-performance gas turbines that utilize ATS and advanced aircraft technology that use natural gas or hydrogen fuels from coal.
- Unique fuel cell turbine hybrid cycles that incorporate intercoolers, humidified air cycles, and high-pressure ratios to achieve the highest efficiency.
- High-efficiency coproduction (electricity and hydrogen) energy systems, utilizing waste heat for making hydrogen from natural gas.
- Integration in the long term of CO_2 capture technologies with all of the above systems.
- Integration of fuel cells with other heat engines (reciprocating engines, Stirling engines, etc.) to create highly efficient and clean power modules.
- Fuel cell systems, including high- and low-temperature units.

Representative Technologies

- Low- and high-temperature fuel cells.
- Optimized gas turbines with higher-pressure ratios, intercoolers, oil-less bearings.
- Smart control systems.
- Hydrogen separation membranes.
- Natural gas reforming.
- CO_2 capture.
- Membrane separators for air, hydrogen, and CO_2.
- Ultra-high temperature steam turbines.

Technology Status/Applications

- Two different fuel cell turbine hybrid power systems (300 kW) have been designed, built, and operated (Siemens Westinghouse and FuelCell Energy Inc.). Both prototype systems logged more than 3,000 hours of operation each and achieved efficiencies of approximately 52% with near-zero emissions.
- The Solid State Energy Conversion Alliance (SECA) is in the second year of an eight-year program to develop low-cost (< $400 / kW) fuel cell modules for standalone and hybrid applications.
- Micro gas turbines (available now) and certain fuel cell systems are being used now in industrial and residential (limited) applications for both power and heat.
- Proton-exchange membrane, fuel cells are available now.
- Solid oxide fuel cell technology has demonstrated long-term performance (see first bullet above). ATS spin-off technologies are being infused into mature product lines in commercial operation.
- ATS gas turbines are engaged in large-scale demonstration and poised for commercial deployment for retrofitting existing plants, for new central-station technology, and for onsite or distributed power generation.
- High-temperature fuel cells – such as molten carbonate and tubular solid oxide – are engaged in commercial-scale demonstration tests, but not yet competitively on the market.
- Fuel cells and turbines are being integrated and demonstrated at commercial scales.
- Various elements of high-performance cycles need to be developed to integrate long-term CO_2 capture, membrane separation, optimized turbines, low-cost high-performance SECA fuel cells, and ultra-high temperature steam turbines need extensive development.

Current Research, Development, and Demonstration

RD&D Goals

By 2010

- Demonstrate integrated fuel cell and turbine systems achieving efficiencies of 60% on natural gas.
- Reduce the costs of the Solid-state Energy Conversion Alliance fuel cell power system to $400/kW.

By 2020

- Demonstrate integrated fuel cell and turbine systems achieving efficiencies of 60% on coal and 75 % on natural gas.
- Integrate optimized turbine systems into zero-emission power plants.

By 2030

- Demonstrate fuel cell hybrid systems incorporating carbon capture methods that achieve near-zero CO_2 emissions to the environment.

RD&D Challenges

- Low-cost, high-performance materials.
- Compatible fuel cell and micro-gas-turbine components.
- Simpler manufacturing process and materials in fuel cells to lower costs.
- Grid interconnection.
- Reforming technology.
- Fuel cell turbine control system for steady-state and dynamic operation.
- System-specific energy-efficient environmental controls for NO_x.
- Developing new components required by long-term cycles integrating CO_2 capture.

RD&D Activities

- High-temperature fuel cell performance advancement for FCT hybrid application.
- Development of large gas turbines for FCT hybrid application.
- Systems integration and controls for hybrid FCT application.
- Hybrid systems and component demonstration.
- Low-cost fuel cell systems.
- Develop hydrogen separation, transport, and storage.
- Develop methods for CO_2 sequestration and/or capture.

- Develop high-performance materials, catalysts, and processes for reforming methane.
- Develop membranes for separation of air, hydrogen, and CO_2.

Recent Progress

- Siemens-Westinghouse has demonstrated a nominal 300 kW fuel cell turbine direct-cycle hybrid for more than 3,000 hrs. and achieved an electrical efficiency of 53%.
- FuelCell Energy, Inc., (FCE) has demonstrated a nominal 300 kW fuel cell turbine indirect cycle hybrid for more than 6,000 hrs. and achieved an electrical efficiency of 52%. FCE is currently building a fully integrated version of their 300 kW hybrid.
- Siemens-Westinghouse demonstrated a 25-kW solid oxide fuel cell for more than 13,000 hours and a 125-kW unit for more than 14,000 hours.
- The ATS program has resulted in successful design, fabrication, and testing of a gas turbine power system.
- ATS technologies developed for the ATS machine are being infused into mature gas turbine product lines yielding significant savings in fuel and emissions.
- The first commercially sold Advanced Turbine System (ATS) has been deployed by GE to Baglan Bay, U.K. The 400 MW (50 Hz.) 60% efficient unit has passed the commercial acceptance test and met power output and emissions requirements. By the end of 2003, the machine will be commercially deployed.

Commercialization and Deployment Activities

- Fuel cells are becoming viable in niche applications, and increased production rates are expected to lower capital costs.
- More than 200 fuel cell units (mostly 200-kW size) are operating worldwide.
- Currently, there are six industrial teams in the SECA program developing low-cost (< $400/kW) solid oxide fuel cell technology. The SECA program is supported by a significant core technology program to resolve technical issues. Three of the six SECA industry team have shown significant interest in developing fuel cell turbine hybrid products.
- Ballard is the primary developer of proton exchange membrane fuel cells.
- Energy losses and cost are expected to decline with system refinements.
- ATS technologies such as brush seals, coatings, and compressor technology are currently being used in a majority of the latest turbine designs.

Market Context

- Fuel cell technology would provide power and space conditioning to residential, commercial, and industrial developments.
- Large domestic and international markets, greater than 200 GW both domestically and internationally. Potential applications include retrofitting existing plants and building new central-station capacity.