Title

# Hybrid Fuel Cell Systems



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Examples of hybrid fuel cell power generation cycles are the combine high-temperature fuel cells and gas turbines, reciprocating engines, or another fuel cell. These represent the hybrid power plants of the future. The conceptual systems have the potential to achieve efficiencies greater than 70 percent and be commercially ready by year 2010 or sooner. The hybrid fuel cell/turbine (FC/T) power plant will combine a high-temperature, conventional molten carbonate fuel cell (MCFC) or a solid oxide fuel cell (SOFC) with a low-pressure-ratio gas turbine, air compressor, combustor, and in some cases, a metallic heat exchanger (1). The synergistic effects of the hybrid fuel cell/turbine technology will also provide the benefits of reduced greenhouse gas emissions. Nitrous (NOx) emissions will be an order of magnitude below those of non-fuel cell power plants and carbon monoxide emissions will be less than 2 parts per million (ppm) (2). There will also be a substantial reduction in the amount of carbon dioxide produced as compared to conventional gas power plants.

Fuel cells are inherently attractive for distributed power applications, but their use is limited by the need to package them in a system balance of plant (BOP) that allows them to function effectively. All fuel cells, especially high-temperature fuel cells, require spent fuel utilization/waste heat recovery subsystems. Low-temperature fuel cells also require fuel reforming subsystems. A common approach for providing these BOP functions has been to integrate the fuel cell with another generating technology.

There can be many different cycle configurations for the hybrid fuel cell/turbine plant. In the direct mode, the fuel cell serves as the combustor for the gas turbine while the gas turbine is the balance-of-plant for the fuel cell, with some generation. In the indirect mode, the fuel cell uses the gas turbine exhaust as air supply while the gas turbine is the balance of plant. In indirect systems, high-temperature heat exchangers are used (3).

For certain distributed power applications, fuel-cell/fuel-cell hybrids may be an effective approach to the BOP problem. Only certain combinations of fuel cells promise to synergize into a simplified BOP. Generally these team a high temperature internally reforming fuel cell with a low temperature fuel cell having a complementary electrolyte (anion-conducting versus cation-conducting electrolytes). The SOFC/PEFC hybrid (solid oxide fuel cell/polymer electrolyte fuel cell) is of particular interest. Both fuel cells are the focus of current R&D programs, and the following synergisms are inherent:

- *SOFC as Reformer for the PEFC* - fuel utilization in the SOFC is limited to a range necessary only to reform natural gas, but not completely oxidize it.

- *PEFC as Chemical Bottomer for the SOFC* - reformed fuel utilization is completed in the PEFC, where more favorable thermodynamics apply.

- *Inherent Sequestration Compliance* - bulk air separation or acid gas removal is not required for isolation of CO2, if sequestration is ultimately practiced in some way.

- *Coproduction and Load Following Options* - coproduction of hydrogen, possibly in conjunction with a storage system, allows the SOFC to be base loaded, while cycling is more effectively done with the PEFC.

The hybrid system is key to the Department of Energy's Vision 21 plants. The Vision 21 program has set power plant goals of achieving efficiencies greater than 75 percent (LHV) for natural gas. The higher efficiencies play a key role in reducing emissions, another target in Vision 21 plants. As a comparison, conventional coal-burning power plants are typically 35 percent efficient and natural gas fired plants are now 40 to 50 percent efficient. Figure 1 shows the estimated efficiency ranges of current and future power generation systems.

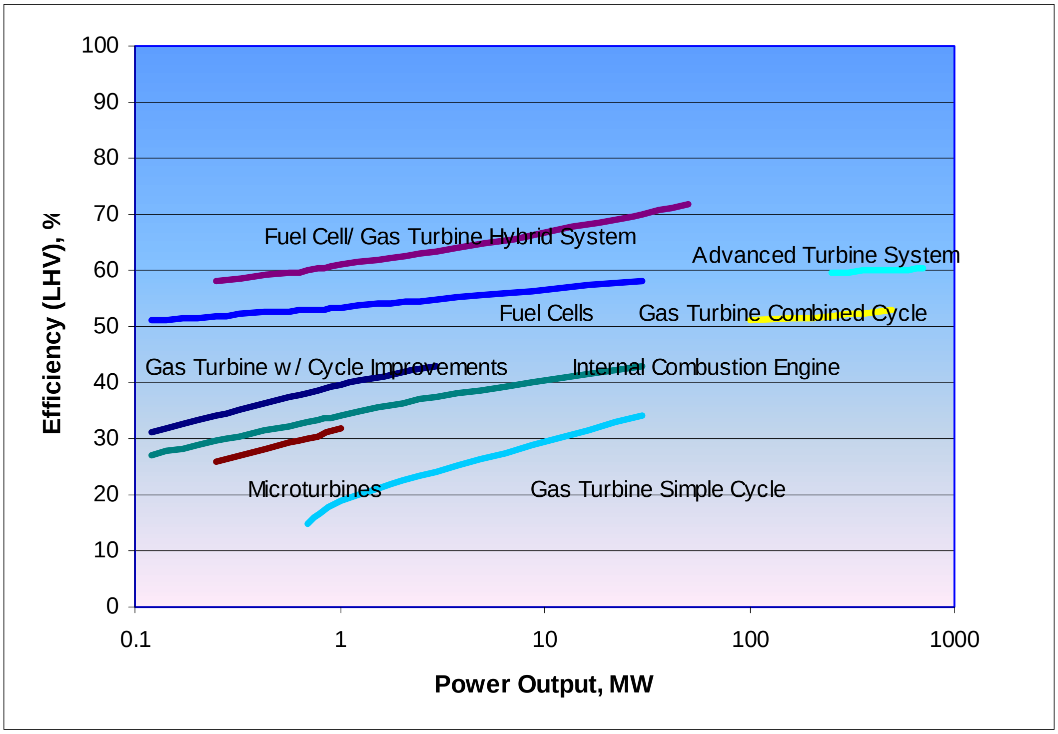


Figure 1. Estimated performance of Power Generation Systems

The combination of the fuel cell and turbine operates by using the rejected thermal energy and residual fuel from a fuel cell to drive the gas turbine. The fuel cell exhaust gases are mixed and burned, raising the turbine inlet temperature while replacing the conventional combustor of the gas turbine. Use of a recuperator, a metallic gas-to-gas heat exchanger, transfers heat from the gas turbine exhaust to the fuel and air used in the fuel cell. Figure 2 illustrates an example of a proposed fuel cell/turbine system. One item to note in Figure 2 is that the combustor shown prior to the turbine is for startup purposes only.

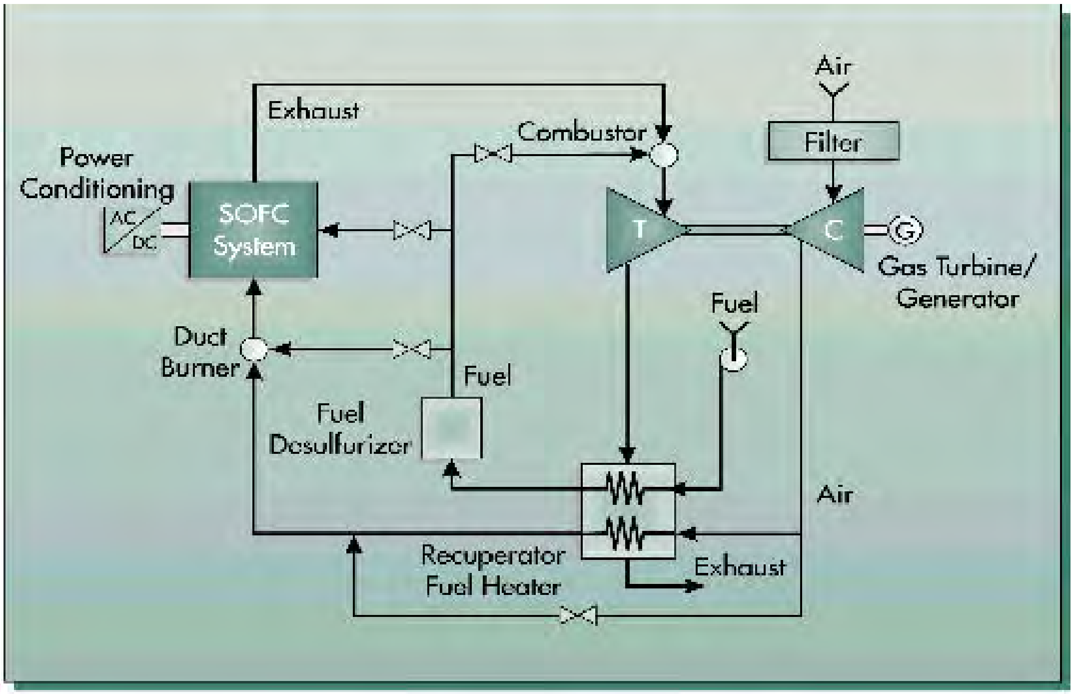


Figure 2. Diagram of a proposed Siemens-Westinghouse hybrid system. (Taken from DOE Project Fact Sheet - Fuel Cell/ATS Hybrid Systems.)

The hybrid plants are projected to cost below comparably sized fuel cells, (4) and be capable of producing electricity at costs of 10 to 20 percent below today's conventional turbine plants (1). Operation of the plant is almost totally automatic. Therefore, it can be monitored and managed remotely with the possibility of controlling hundreds of the power plants from a single location (2).

Initial systems will be less than 20 MW, with typical system sizes of 1-10 MW. Future systems, in the megawatt size, can boost efficiency even further by combining two solid oxide fuel cell modules with more advanced gas turbines and introducing sophisticated cooling and heating procedures. As mentioned above, another possibility of a hybrid power plant is to combine a solid oxide fuel cell with a proton exchange membrane (PEM) fuel cell. The SOFC would produce both electric power and hydrogen. This hydrogen would then be utilized by the PEM to generate more electric power (2).

Countries around the world are developing interest in the high-efficiency hybrid cycles. A 320 kW hybrid (SOFC and gas turbine) plant will enter service in Germany in 2001, operated by a consortium under the leadership of RWE Energie AG. This will be followed in 2002 by the first 1 MW plant, which will be operated by Energie Baden-Wurttemberg AG (EnBW), Electricite de France (EDF), Gaz de France, and Austria's TIWAG (2).

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