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Solid Oxide Fuel Cell Gas Turbine Hybrids for Distributed Generation

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Final Edge of Poster

Solid Oxide Fuel Cell Gas Turbine Hybrids For Distributed Generation

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Abstract

Given the need for clean and reliable energy, fuel cell technologies offer the ability to produce extremely low-emission electricity from reliable fossil energy. A standalone solid oxide fuel cell (SOFC) module can reach electrical efficiencies of about 60%. However, coupling a SOFC to a Brayton style gas turbine (GT) increases the efficiency of the system to 70-75% or more. Using results from NETL's HYPER Lab and published research, this project evaluates the strengths, limitations, and potential applications of SOFC-GT hybrids.

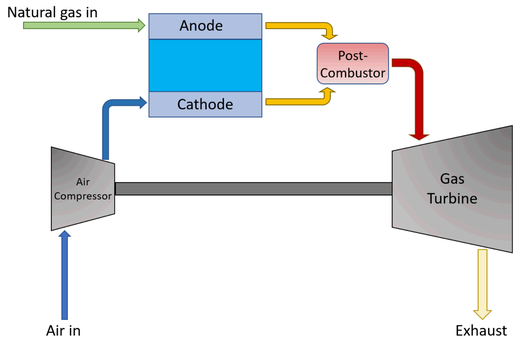

Figure 1. SOFC-GT operating principle

- Improved dynamic response characteristics
- Reduced capital cost compared to a standalone fuel cell
- Extended fuel cell service life (up to 10x)

Maximizing Efficiency

SOFC-GT hybrids have high efficiency by recycling waste thermal energy. Hot fuel cell exhaust spins the turbine. Turbine exhaust then heats incoming air and the methane reformer. The reformer can also be fed with water produced by the fuel cell, creating a near net zero water consumption cycle.

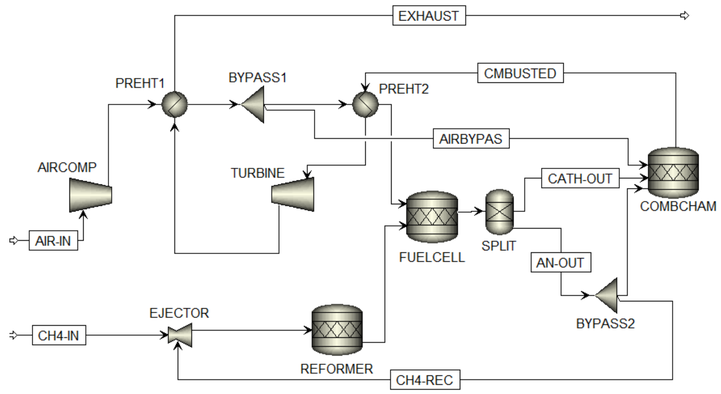

Figure 2. Aspen Plus model of a complete SOFC-GT system. Based on results from Politencnico di Milano, Department of Energy[1]

Clean & Reliable Energy

SOFC-GT hybrids operate at a significantly higher electrical efficiency and with greatly reduced water consumption than traditional thermoelectric plants.

- 20% fewer carbon emissions than NG-CC and 66% fewer CO_2 emissions than coal
- Near water free cycle = Reduced water consumption & thermal pollution
- Potential to be carbon free when H_2 from a carbon free source is used
- 1/3 the space required for an equivalent NG or coal plant

	(units)	SOFC-GT	NG-CC	NG-GT	Coal
Net Electrical Efficiency[2,3]	LHV [%]	70-80%	54-64%	34-44%	32-42%
Emmissions Rate[4]	kg CO2/MWh	325.3	406.6	604.2	960.6
Water Withdrawal[5]	gallon/MWh	~ 0	250 (recirculating) 11,000 (once through)	~ 0	500-1000 (recirculating) 25,000-35,000 (once through)
Water Consumption[5]	gallon/MWh	~ 0	200 (recirculating) 100 (once through)	~ 0	500-700 (recirculating) 150-250 (once through)
Ramp Rate[2,6,7]	%/sec	2.5	1.1	1.4	0.1
Minimum Load (Turndown)[2,7]	%	5	35	40	30

Figure 3. Operating characteristics of several power plant types

Hybrid fuel cell plants are also scalable to a wide range of power outputs while still performing at higher efficiencies than an equivalent thermoelectric plant.

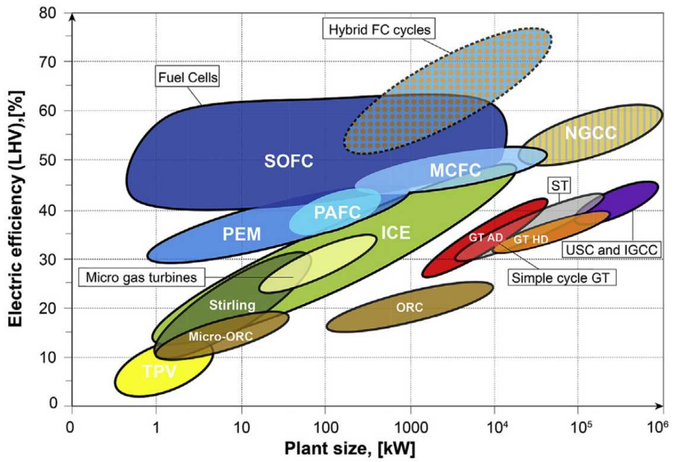

Figure 4. Power plant size vs. Efficiency[1]

Distributed Generation

Distributed generation (DG), the widespread deployment of small output plants, is widely believed to be the next evolution of grid. DG offers benefits such as reducing peak power requirements, cutting transmission/distribution losses, increasing grid resilience and more. Hybrid fuel cells lend themselves well in a distributed generation scenario because of their inherent scalability and efficiency at low output.

- Partial load efficiency loss of only 4-5%
- Turbine can operate independently for fast startup and reserve power
- Fast ramp rates (2-3 %/sec) outperforms traditional thermoelectric plants
  - Provide load following and/or spinning reserves

		DG Benefits						
		Energy Cost Savings	Savings in T&D Losses and Congestion	Deferred Generation Capacity	Deferred T&D Capacity	System Reliability	Improved Power Quality	Reduced Grid Vulnerability
DG Services	Reduce Peak Power Requirement	✓	✓	✓	✓	✓	✓	✓
	Ancillary Services • Operating Reserve • Regulation • Blackstart	✓	✓	✓	✓	✓	✓	✓
	Emergency Power Supply	✓	✓			✓	✓	

Figure 5. Benefits of distributed generation[8]

Coming Up

- Develop stronger materials & reduce manufacturing costs
- Improve control systems & optimize operating parameters

The biggest hurdles for fuel cell technology is extending fuel cell service life and reducing performance degradation. This has the biggest impact on fuel cell system cost and return on investment. SOFC-GT hybrids naturally address certain issues.

- Ceramics inside SOFCs are affordable & mass producible
- Gas turbine reduces necessary fuel cell size (reduces capital cost)
- Gas turbine absorbs sudden load changes (extends fuel cell service life)

SOFC-GT hybrids represent a promising element of fuel cell technology that could play a key part in modernizing the electric grid.

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