# SOFC/GT Fuel Cell Hybrids

The combination of fuel cells and gas turbines into hybrids designs is a game changing technology. The Solid Oxide Fuel Cell/ Gas Turbine (SOFC/GT) offers the potential for 60-70% net electric efficiency, better than the current batch of CCGTs and equivalent to projections for larger SOFC-based central station units, but in sizes small enough to be deployed as distributed generation units. And yes, there is still some cogen possible.

Most of the work to date has been concentrated in cycle studies and optimization, but Siemens-Westinghouse has built and installed a very successful, first of a kind demonstration unit at UC-Irvine. The unit has been tested at 220kW with an advertised 53% LHV net electric efficiency.

In principle, the fuel cell stack replaces the combustor in the normal recuperated cycle, and the turbine's compressor provides pressurized air to the fuel cell. The nominal stack operating temperature for an SOFC is 1000°C, which provides an approximate 850°C non-augmented TRIT to the turbine. At this temperature, operating without co-firing and with a reasonable inlet gas temperature to the recuperator, the optimum pressure ratio is 3 or 4:1. The power split is a nominal 4:1 fuel cell to gas turbine.

The preferred turbine configuration, at least in smaller sizes and certainly for demonstration projects, is one that supports an external combustor and recuperator. Beyond that, there is a strong preference for a single-shaft turbine with an integral motor/generator to allow direct control of the air flow to the SOFC. In addition, the orientation of radial compressor/turbine designs seems to offer advantages in packaging and managing the required high temperature interconnects.

There is a co-firing variation on this arrangement that raises the TRIT to approximately 1150°C and operates at pressure between 9 and 10:1. This arrangement was configured around the Mercury 50 and had the effect of rebalancing the power split to 2:1, fuel cell to gas turbine in this nominal 12MW plant.

Finally, there is an entirely different school of thought that is moving toward high pressure ratio aero derivative designs integrated into various combined cycles and look to be centralized in size and scale.

It should be obvious to all, that what we are witnessing is yet another version of the "On-site" vs. "Sub-station" vs. "Centralized" debate, but in this case, there are no obvious differences in the claimed efficiency horizons among the contenders.

It is also interesting to note that few, if any turbines exist to support the on-site configuration's, and those that do exist need to be de-rated to match the current 850°C TRIT limit, aggravating the already difficult FC/GT cost objectives. The Advanced Microturbine Program, seeking to maximize the stand-alone unit efficiency and cost, has had the effect of pushing TRIT's, pressure ratios and power levels higher, and further away from the fuel cell design optimum.

The long term potential of the SOFC/GT is exciting, and near term strategies should remain on a trajectory that leads to this configuration. In the simplest configuration for on-site applications, this seems to indicate a 950°C TRIT 4.5:1 with a metal wheel, banking on some improvement in managing the temperature loss between the stack and the turbine. At 500kW for the turbine, the SOFC/GT would be a 2.0MW on-site unit.

The introduction ceramic turbine components as part of the Advanced Microturbine Program would be more consistent with the co-firing scheme and a higher pressure ratio, and/or possibly an Intercooled Recuperated (ICR) designs to reduce the overall plant size and cost.

The fuel cells, although still very much in a development mode, are much more easily scaled to match available turbines than the reverse. The SOFC companies, however, will "lead the sale" of future commercialized SOFC/GT products, with gas turbines becoming an important and differentiating component.

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