Hybrid SOFC-GT Systems Analysis

OVERVIEW

Solid oxide fuel cell (SOFC) technology demonstrates remarkable potential for integration with axial turbo-machinery to achieve greater than 75% fuel-to-electric efficiency on natural gas. The NFCRC hosted the world's first demonstration of a pressurized SOFC hybrid system. New simulation tools have been developed to test and evaluate this novel generating concept. Ongoing work in collaboration with the National Energy Technology Laboratory (NETL) in Morgantown, WV is testing novel control strategies focused on dynamic responsiveness and failure mitigation.

GOALS

- Dynamically simulate the highly coupled physics of a fuel cell gas turbine hybrid
- Simulate the rapid dynamics of a stall/surge phenomena in a recuperated micro-turbine system.
- Develop advanced control for the mitigation and avoidance of compressor stall/surge

RESULTS

Research into the fuel cell gas turbine concept has been ongoing at the NFCRC for more than a decade. Numerous experimental and numerical studies have been employed to understand the complex behavior of these systems. Figure 1 illustrates the model calibration to experimental data from a Capstone C65 micro-turbine tested at the NFCRC. This advanced recuperated micro-turbine design is a good candidate for future hybridization. The on-going tests at NETL utilize a Garrett85 turbine with a software-in-the-loop strategy to simulate the thermal dynamics of a fuel cell. The introduction of a large volume of air and significant pressure drop between the compressor and expander increases the likelihood of compressor stall/surge, wherein a buildup of back pressure causes the compressor blades to stall and flow to reverse through the engine. A single stall/surge incident could be catastrophic to a fuel cell hybrid. This work developed a unique method of simulating the compressor dynamics leading up to and during a stall/surge incident. This enabled controls development which mitigates risk by ensuring substantial surge margin during transient operation.

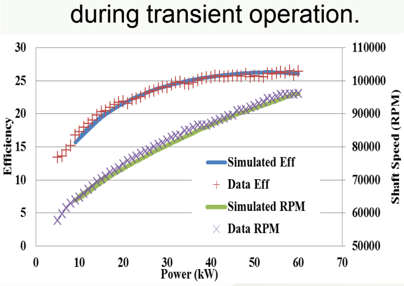

Figure 1. Capstone C-65 micro turbine efficiency and shaft speed

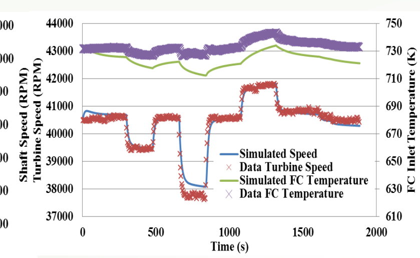

Figure 2. System response of NETL Hyper facility to fuel flow perturbations

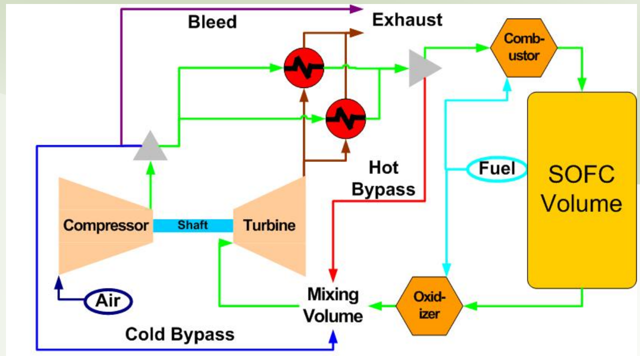

Figure 3. FC-GT topping cycle configuration tested at NETL

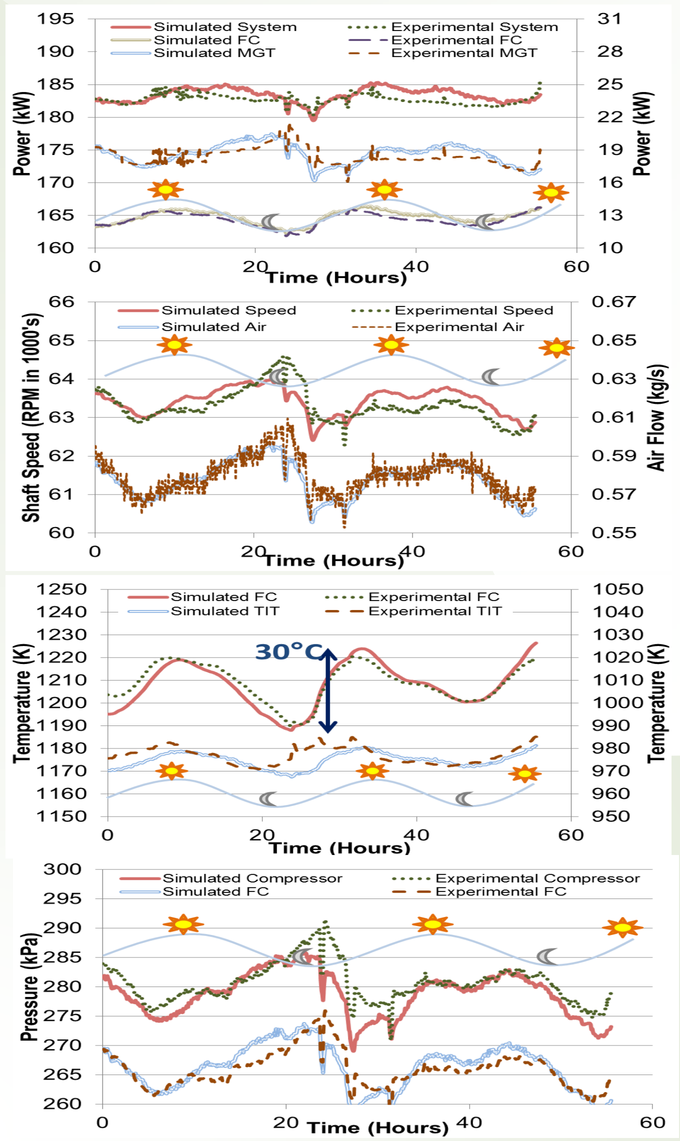

Figure 4. Experimental and simulated open loop response to ambient thermal fluctuations

RESULTS (continued)

The initial test of the Siemens 220kW hybrid system at the NFCRC generated experimental data and provided insights into numerous challenges in the design and control of hybrids. The highly coupled nature of the turbine and fuel cell can be seen in the exacerbation of ambient perturbations experienced by this system. Small ambient temperature variations (12°C) resulted in large stack temperature dynamics (30°C) and power output fluctuations. The dynamic model was able to capture the highly coupled system behavior.

RECENT PUBLICATIONS/PAPERS

D. McLarty, Y. Kuniba, J. Brouwer, S. Samuelsen, "Experimental and theoretical evidence for control requirements in solid oxide fuel cell gas turbine hybrid systems", *J. Power Sources*, 2012, 209, Pages 195-203

PERSONNEL

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