FuelCell Energy
Ultra-Clean, Efficient, Reliable Power

Project Fact Sheet

# Control Modules for Hybrid Fuel Cell/Gas Turbine Power Plants

**Introduction**

FuelCell Energy, Inc. and its partners have conducted a study of dispersed control module implementation strategy for a fuel cell power plant. The overall goal of this study was to develop advanced and intelligent control algorithms for hybrid fuel cell/gas turbine (FC/T) power plants. The study included the following specific objectives:

- Establish a dynamic modeling environment to facilitate simulation studies, as well as development and testing of control algorithms.
- Increase reliability and availability to extend service life of the components in the hybrid FC/T power plant.
- Develop robust controllers that maintain stable operation and high performance in the presence of disturbances.
- Develop optimal control strategies to improve performance and to accommodate fast response during rapid transients.
- Accommodate measurement errors, as well as sensor and actuator faults to reduce the number of unplanned shutdowns.
- Integrate robust and optimal controllers into an overall supervisory framework.

The control system for Fuel Cell/Turbine hybrid power plants enables synergistic operation of subsystems, improving reliability of operation, and reducing frequency of maintenance and downtime. The control strategy plays a significant role in system stability and performance as well as ensuring the protection of equipment for maximum plant life. Figure 1 shows a simplified process diagram of an internally reforming SOFC/T system used for development of advanced control algorithms.

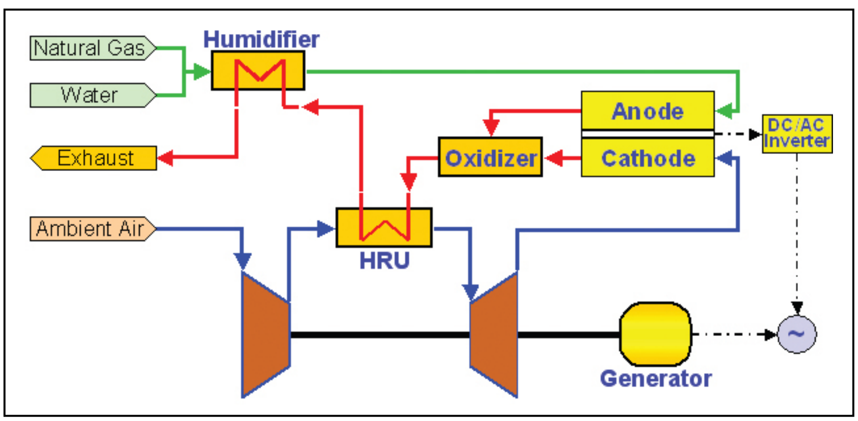


**Figure 1:** Conceptual process flow diagram for SOFC/T system.

The system is based on an indirectly heated Brayton cycle. The anode exhaust, which contains the remainder of the fuel, is mixed with the cathode exhaust in a catalytic oxidizer, where oxidation of fuel is completed. The hot oxidizer exhaust passes through a heat recovery unit in which it preheats the compressed air before entering the turbine. The hot compressed air is expanded through the turbine section, driving an electric generator.

Development of an advanced control strategy was facilitated by using a dynamic model both as a simulation test bed and as part of the controller itself. Components of the advanced control module include a neural network supervisor, robust feedback controllers, and predictive system models. These advanced control components were used in the development and demonstration of an innovative algorithm that optimally controls hybrid power systems, and is easily adaptable to the type of fuel used, whether natural gas, coal gas, or digester gas.

**Approach**

The advanced control module shown in Figure 2 is based on a feed forward/feedback structure.

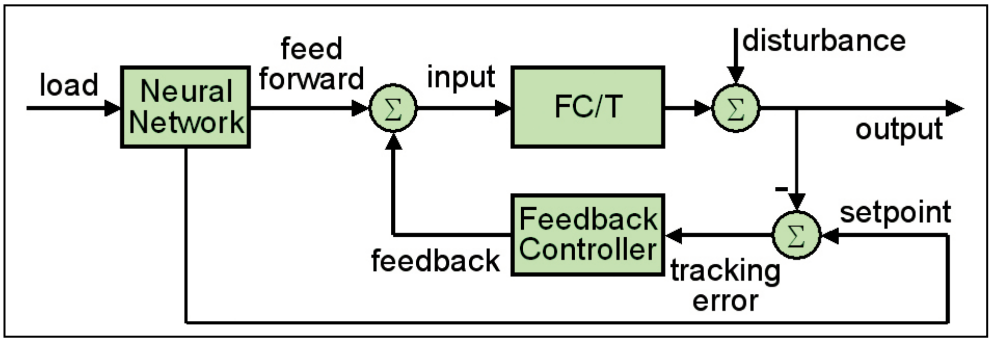


**Figure 2:** Advanced control module comprising neural network supervisor and feedback controller.

The module consists of a combined robust controller and a neural network supervisor that together manipulate the actuators to optimally control the hybrid system during load ramps. The feed forward controller provides optimal dynamic scheduling based on the prescribed load profile and trends. Because the optimization routines are computationally too intensive for real-time application, they are carried out off-line. The resulting data is then used to train a neural network supervisor. The feed forward controller performance depends strongly on the accuracy of the model employed to tune it. A feedback control strategy is utilized to compensate for set point deviations caused by imperfect feed forward control moves and to counteract process disturbances such as variations in fuel composition and ambient temperature.

A comprehensive set of component models was developed and implemented in MATLAB/Simulink. The models include software programs (modules) for internally reforming DFC and SOFC stacks, a microturbine, and balance-of-plant equipment. Integrated system models were developed for both SOFC/T and DFC/T systems based on the component-level models. The modular nature of the computer models in Simulink allows for flexibility in development of integrated system models.

The integrated dynamic system models were utilized to refine the control strategy of the DFC/T system for start-up of the microturbine and fuel flow, as well as for control of the cathode inlet temperature throughout the operating range. The underlying principle for the developed control strategy is optimization of the waste heat recuperation to maximize the turbine inlet temperature and power generation. The strategy was implemented in the dynamic models to simulate and verify start-up and load operations of a sub-MW class hybrid power plant.

**Partners:**
National Fuel Cell Research Center (NFCRC), Irvine, CA
Carnegie Mellon University (CMU), Pittsburgh, PA
Pennsylvania State University (PSU), State College, PA

**Contact:** Hossein Ghezel-Ayagh, Project Manager   (203) 825-6048 hghezel@fce.com