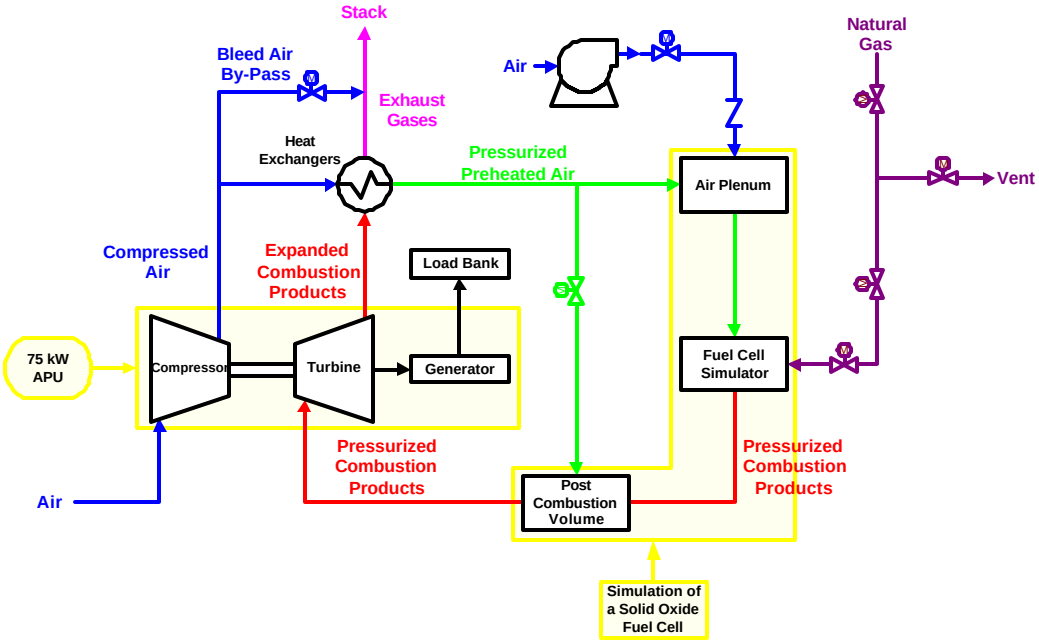
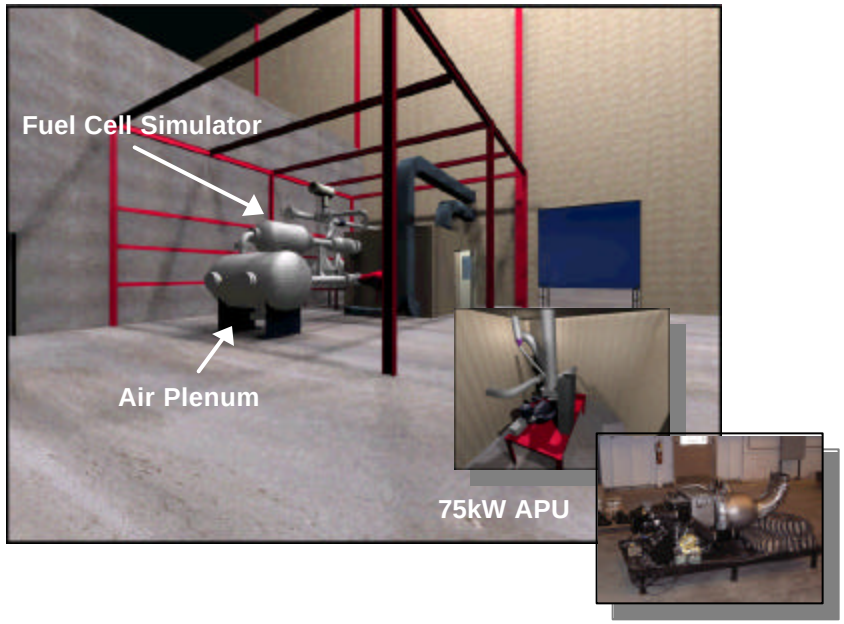
Hybrid Performance (Hyper) Project: Controls for Fuel Cell Integration





to **National Fuel Cell Research Center** **April 3 - 4, 2003**

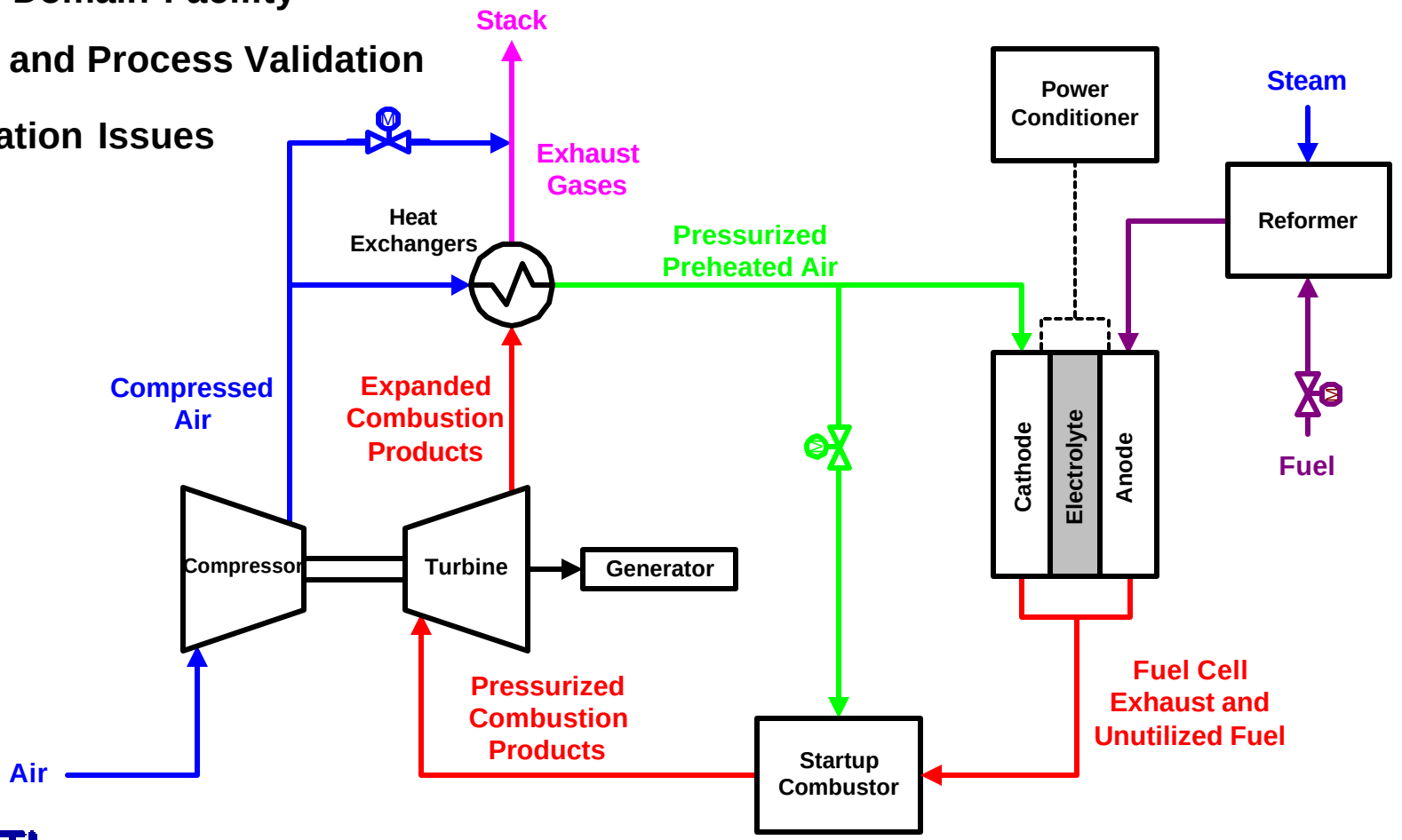
Larry Lawson, Electronics Engineer, Combustion & Engine Dynamics

National Energy Technology Laboratory, USDOE (NETL.DOE.GOV)

Objective

Provide solutions to the problems associated with coupling a fuel cell and a gas turbine in a hybrid power generation facility.

- **Public Domain Facility**
- **Model and Process Validation**
- **Integration Issues**



Power Generation Issues Facing the Utilization of Fuel Cells

- Energy is the product of power and time.
- Few practical methods to store electrical energy in alternating current form.
- Power is current flow as a stiff function of mechanisms of voltage and phase.
- The economic desire is to maintain a base load on the most cost effective units
- The greatest source of problems stem from material properties.
- Reality: faults happen on the grid and within generating unit components.
- Processes designed for steady state, base loading have dynamic constraints.
- Spinning reserve power demands a premium price.
- Inevitably dynamics happen, and controls must protect safety and integrity of equipment and systems.

Transient Events: Testing and Analysis

- Start-up and Shut-down

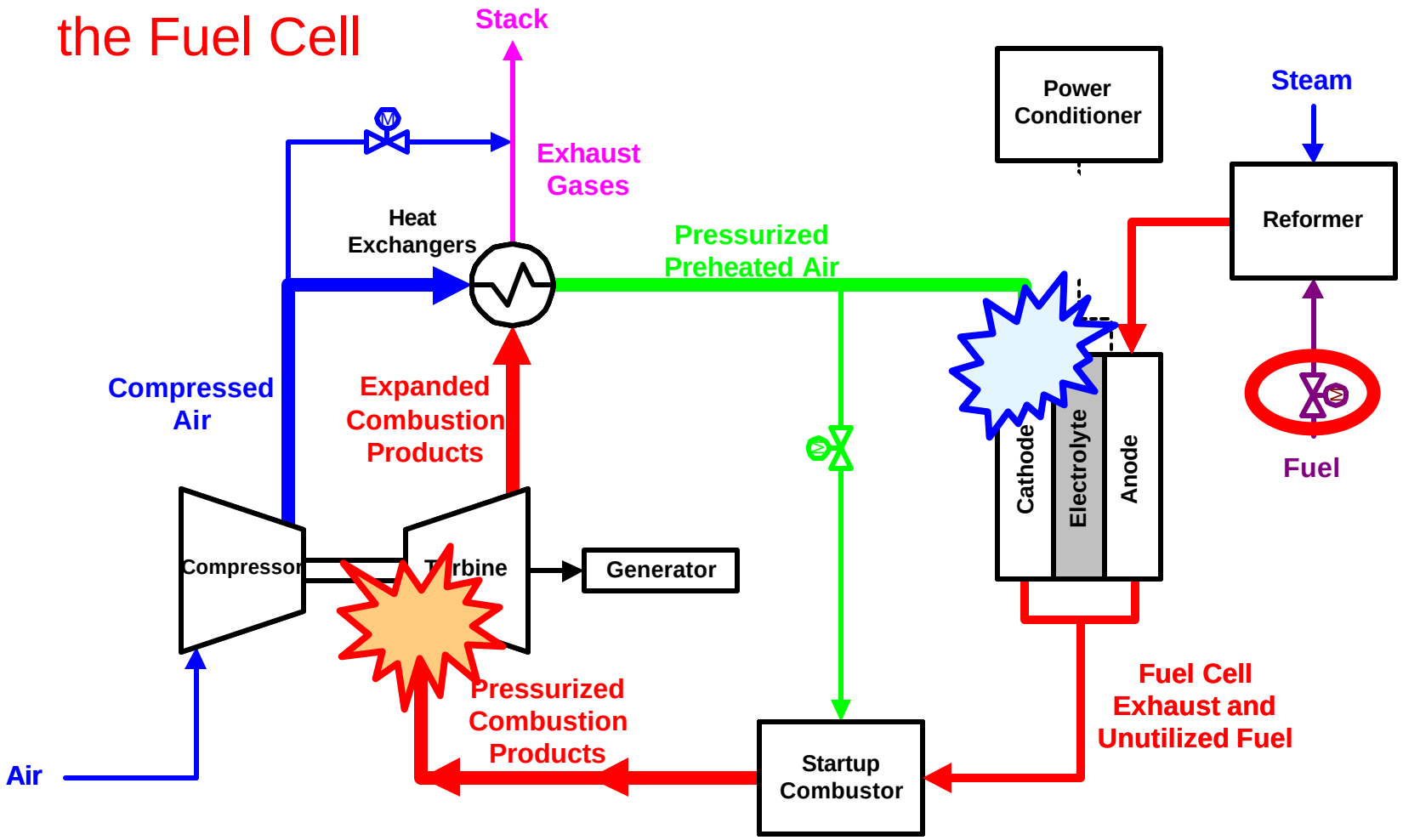
- Load changes on the fuel cell
- Load changes on the turbine/generator

- Fuel cell load following
- Gas turbine load following

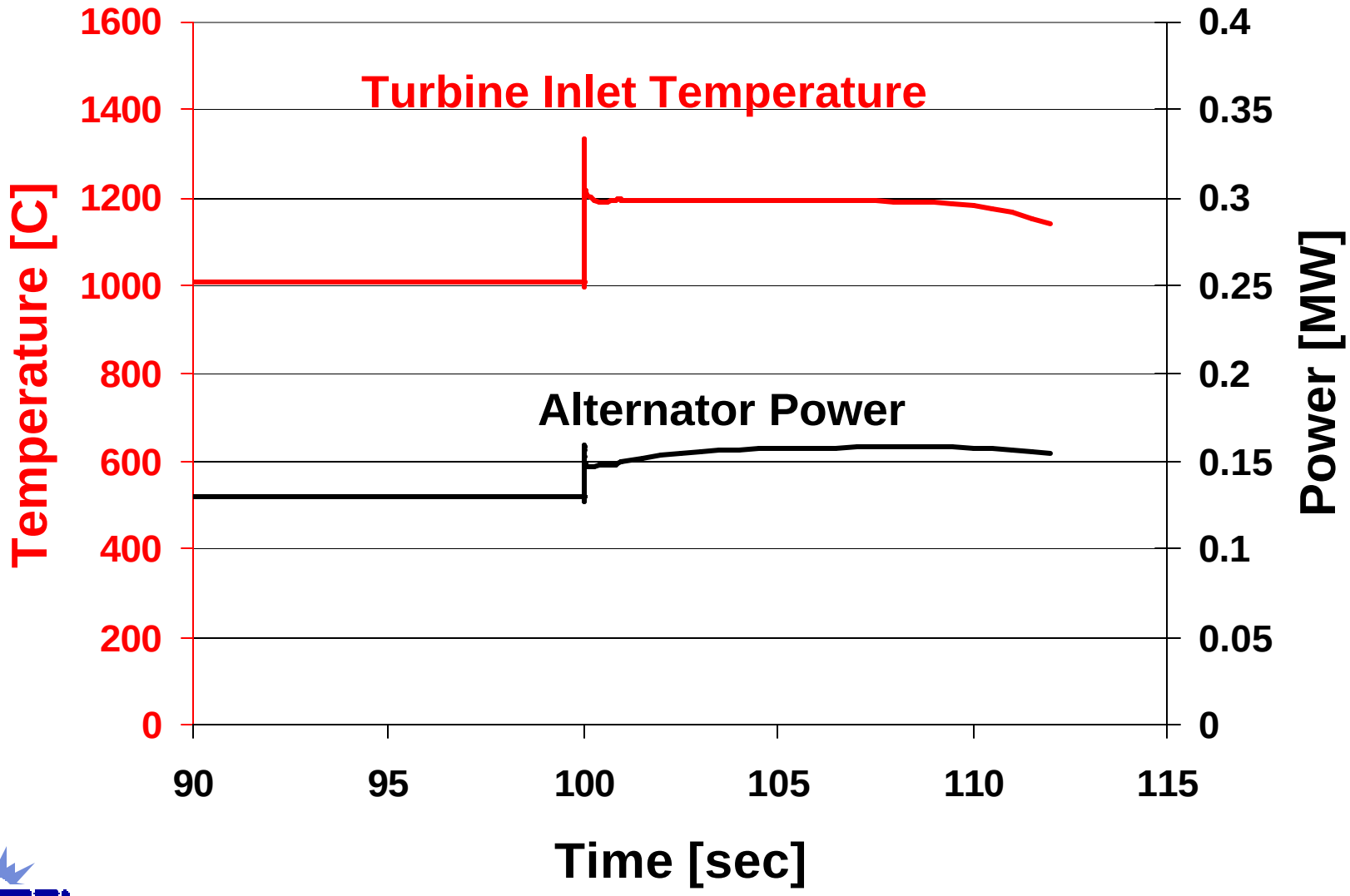
- Compressor stall and surge

Transient Analysis

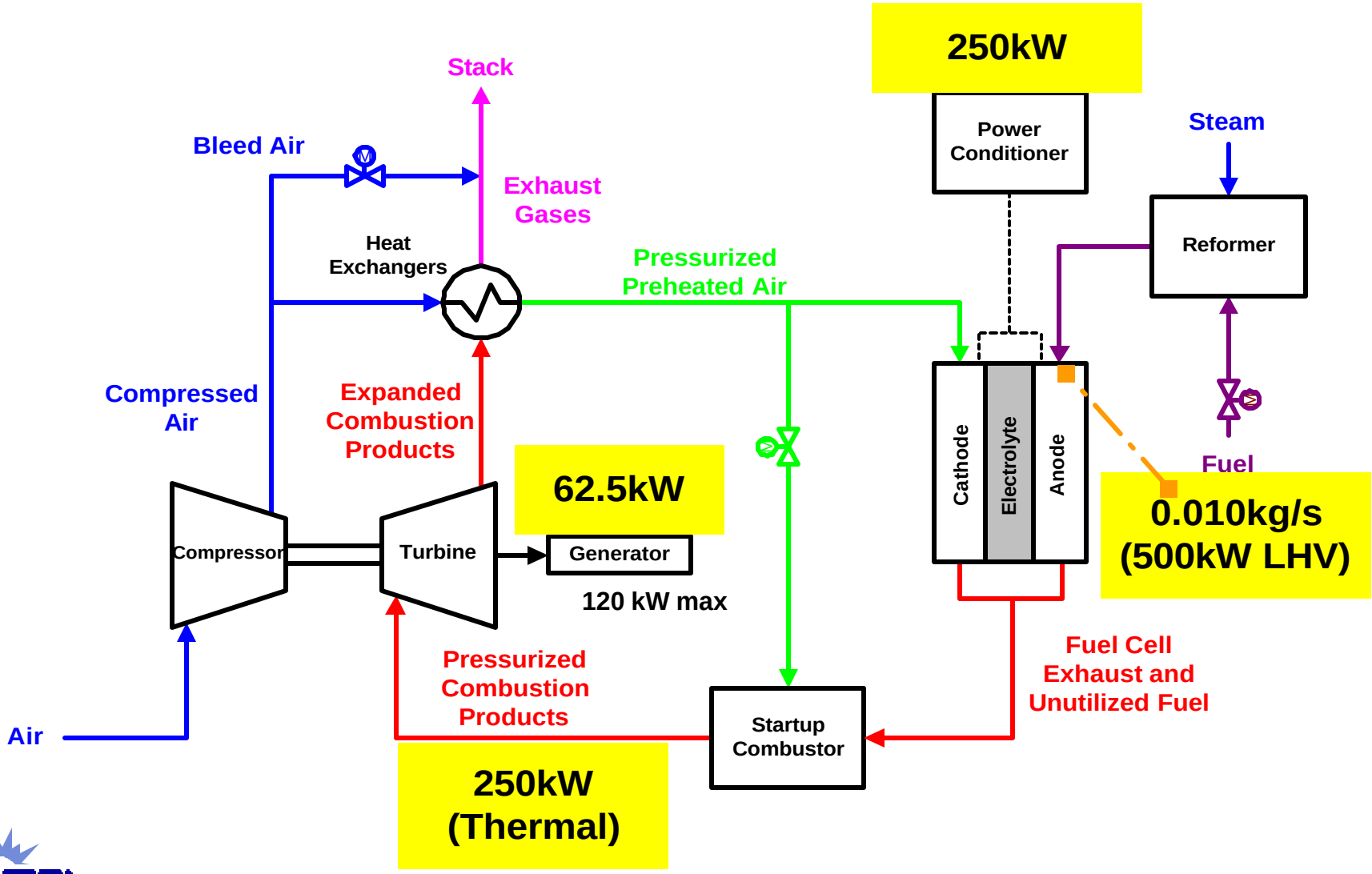
Loss of Load to the Fuel Cell



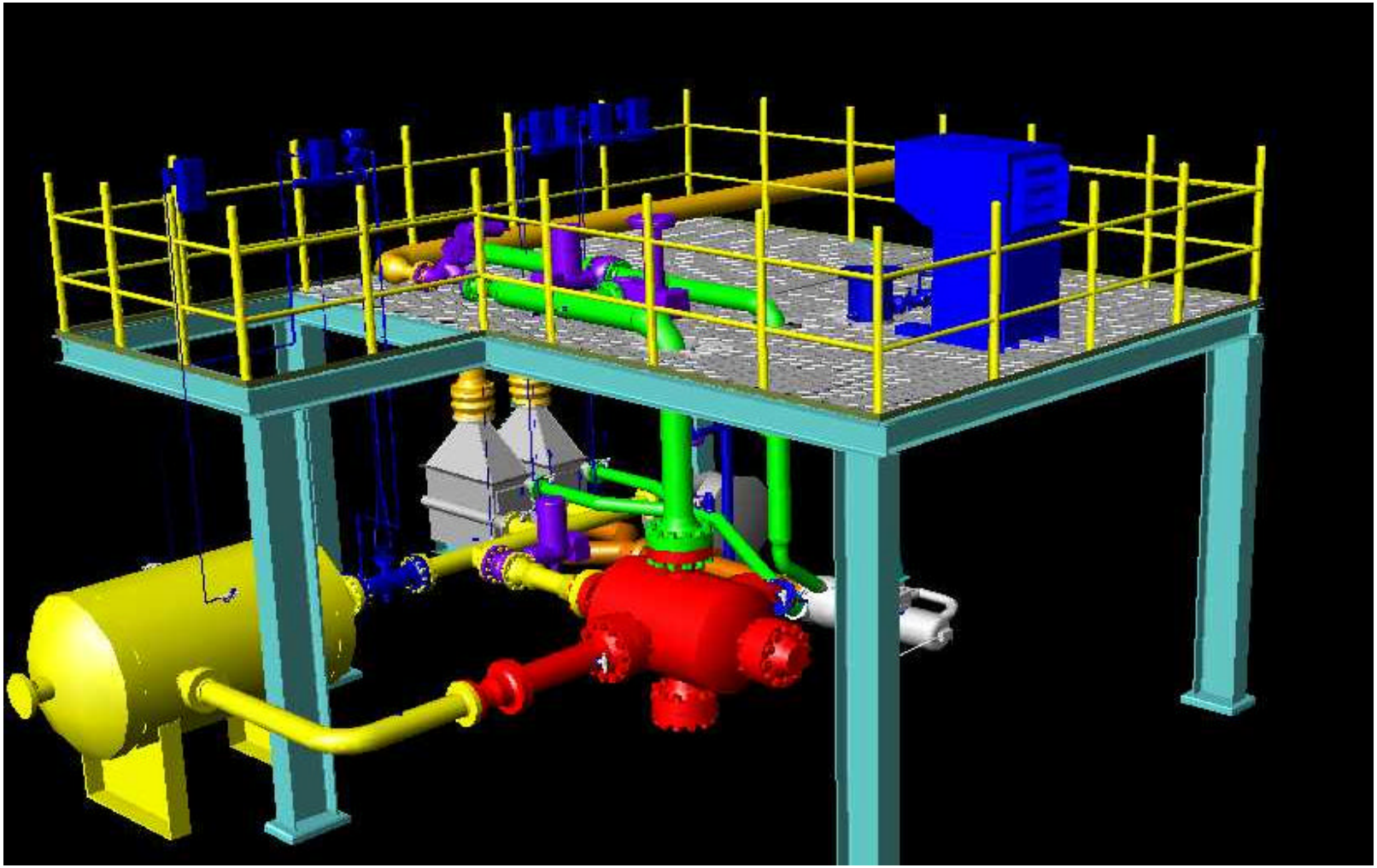
Fuel Cell Load Shedding: Excess Fuel to Turbine



Hybrid Base Loading Operating Condition: Turbine Over-Capacity to absorb transient

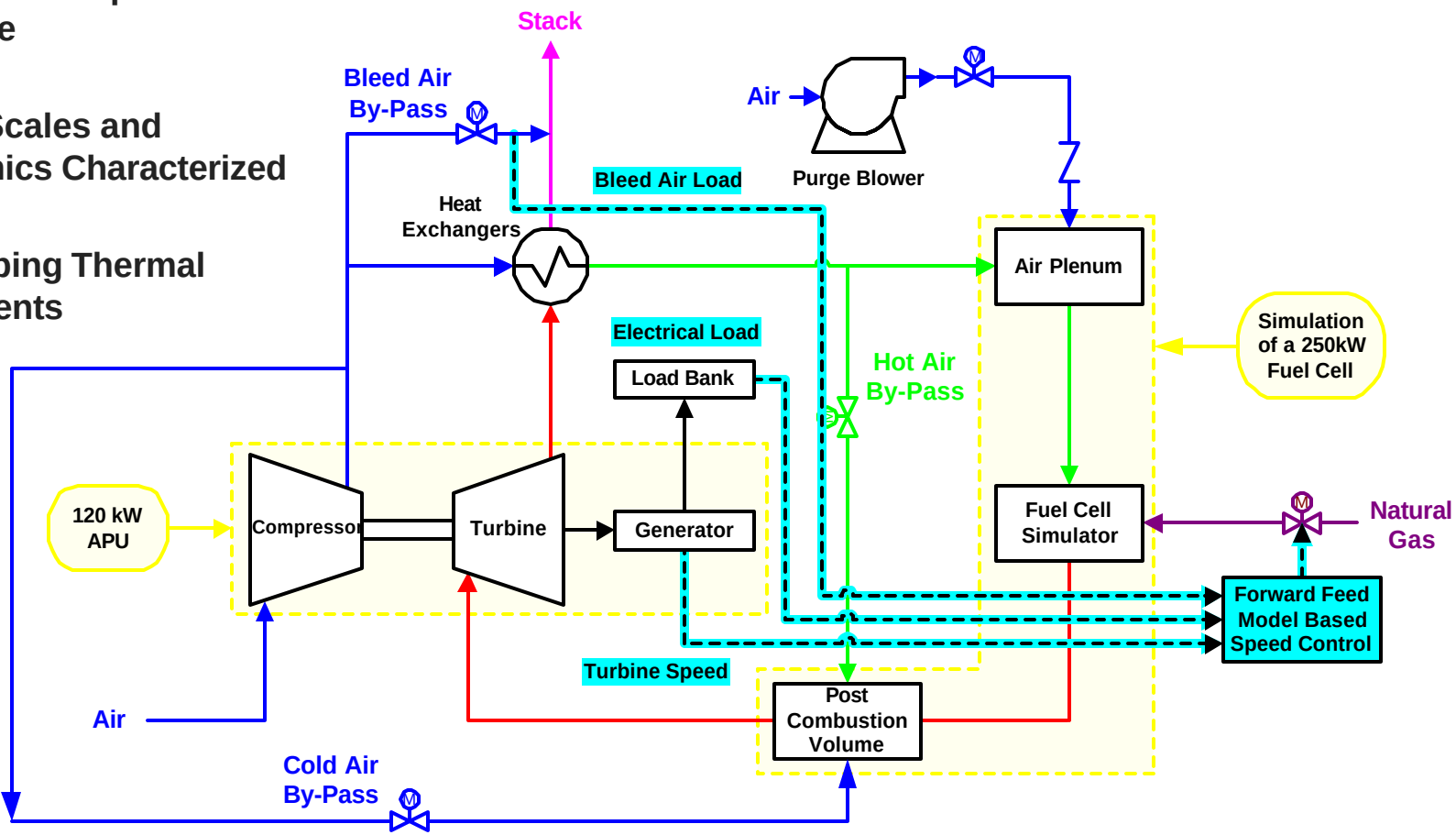


Experimental Simulation Facility

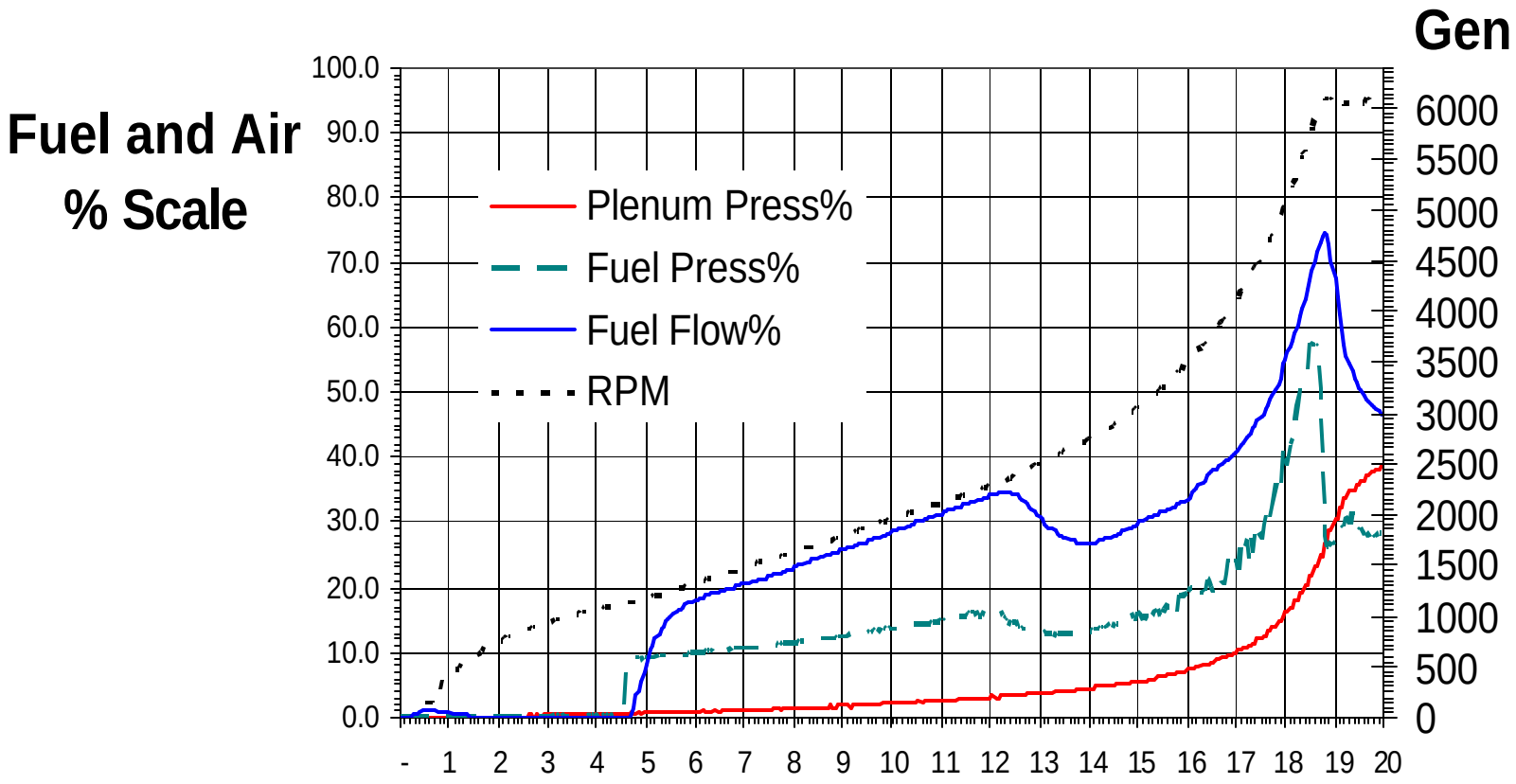


Research Plan- Phase I
Speed Control and System Characterization

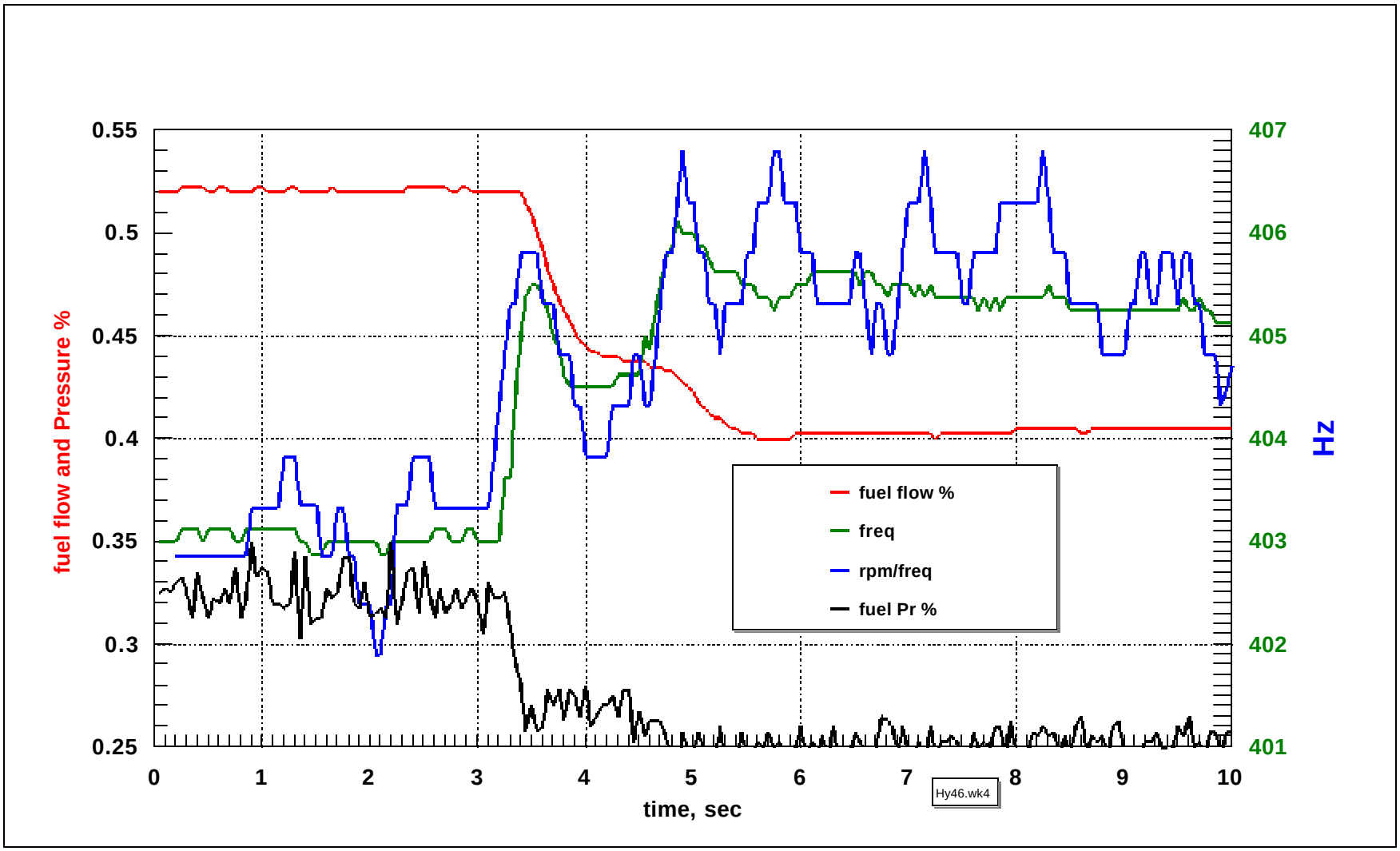
- Effective Speed Control During Startup and Load Change
- Time Scales and Dynamics Characterized
- Absorbing Thermal Transients



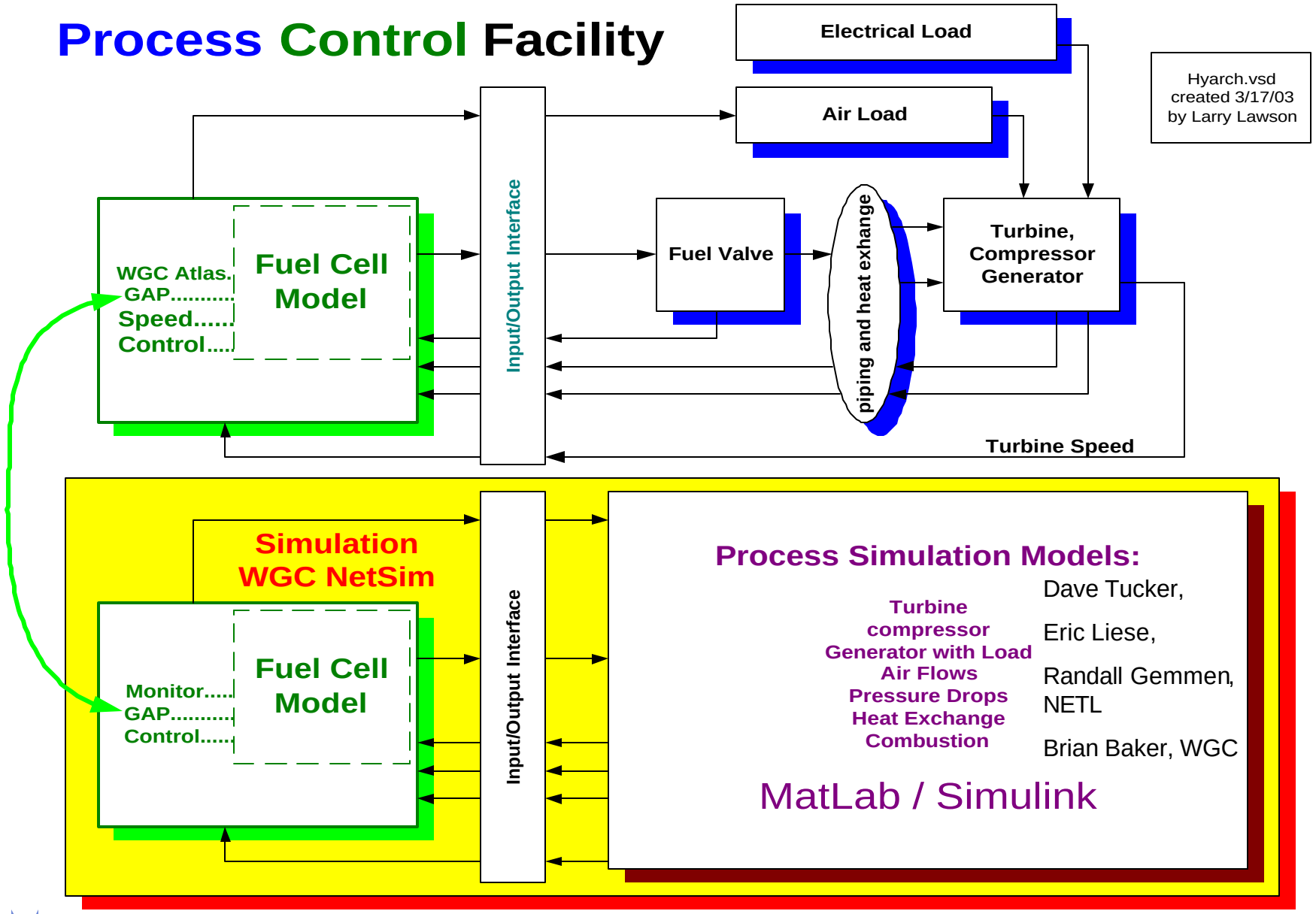
Turbine Power Unit Start-Up Dynamic



Turbine/Generator 45 kW Load Shed Transient:

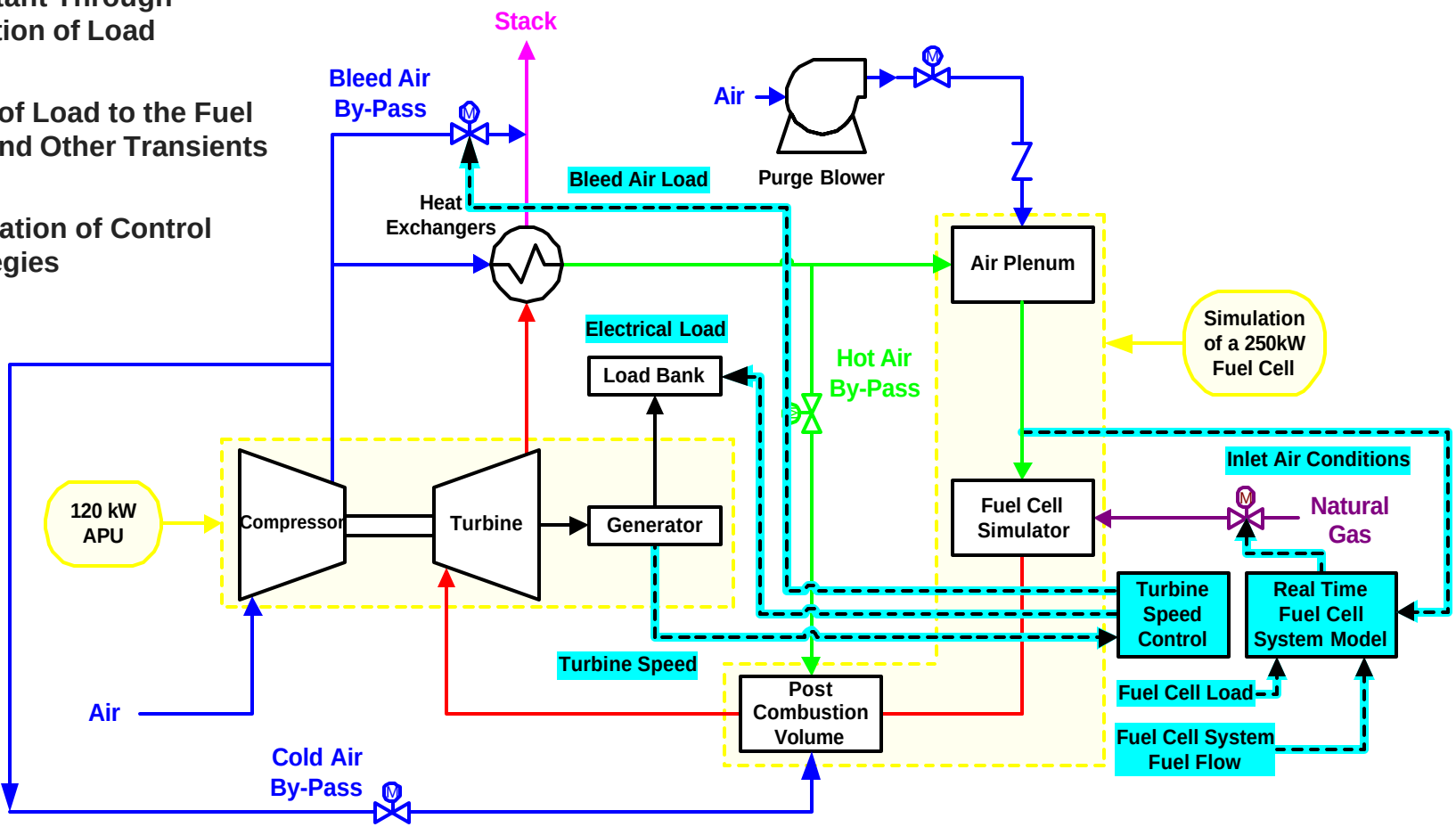


Process Control Facility



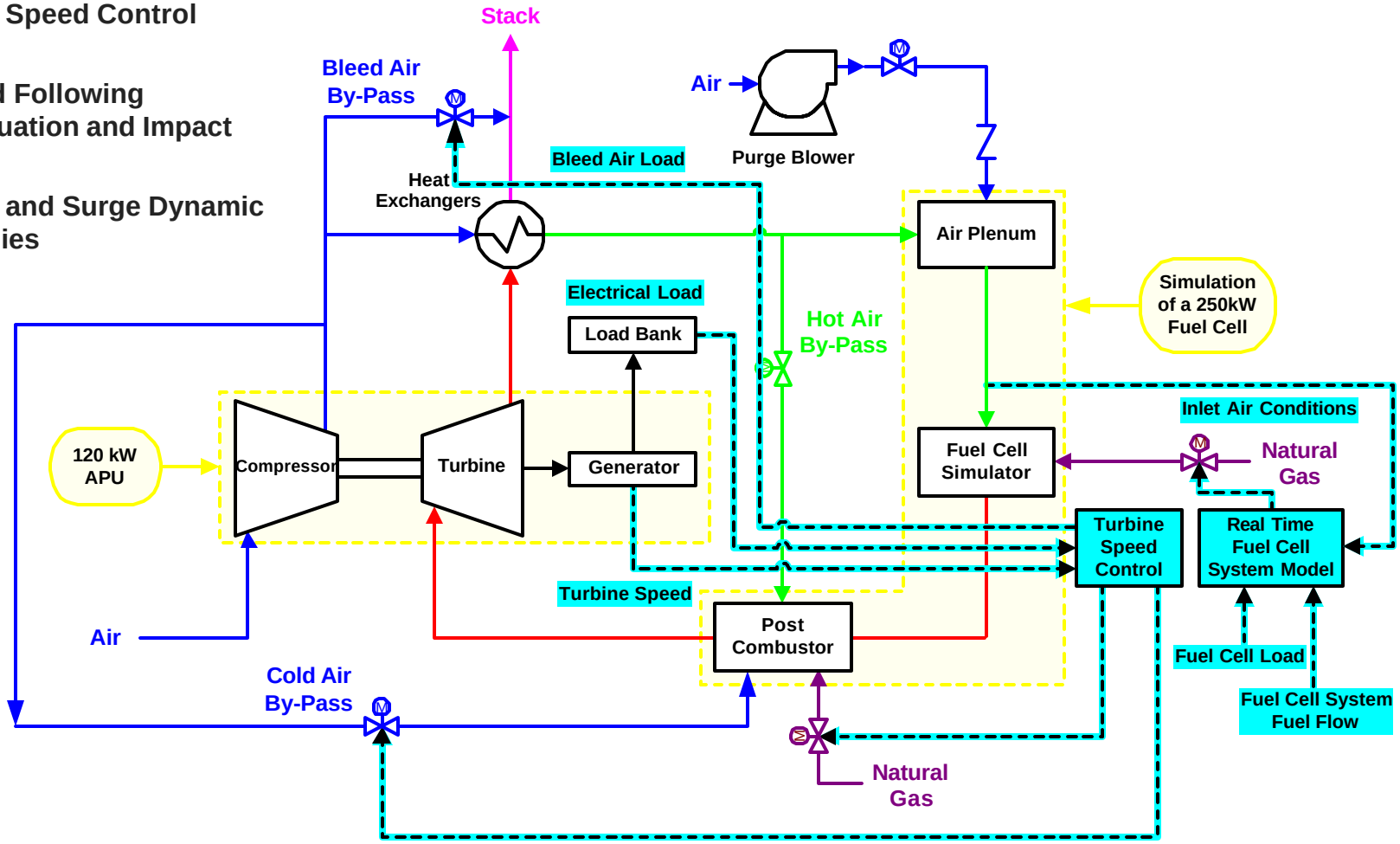
Research Plan- Phase II
Fuel Cell Simulation

- Integration of Alternative Real Time Fuel Cell Model
- Turbine Speed Held Constant Through Variation of Load
- Loss of Load to the Fuel Cell and Other Transients
- Evaluation of Control Strategies



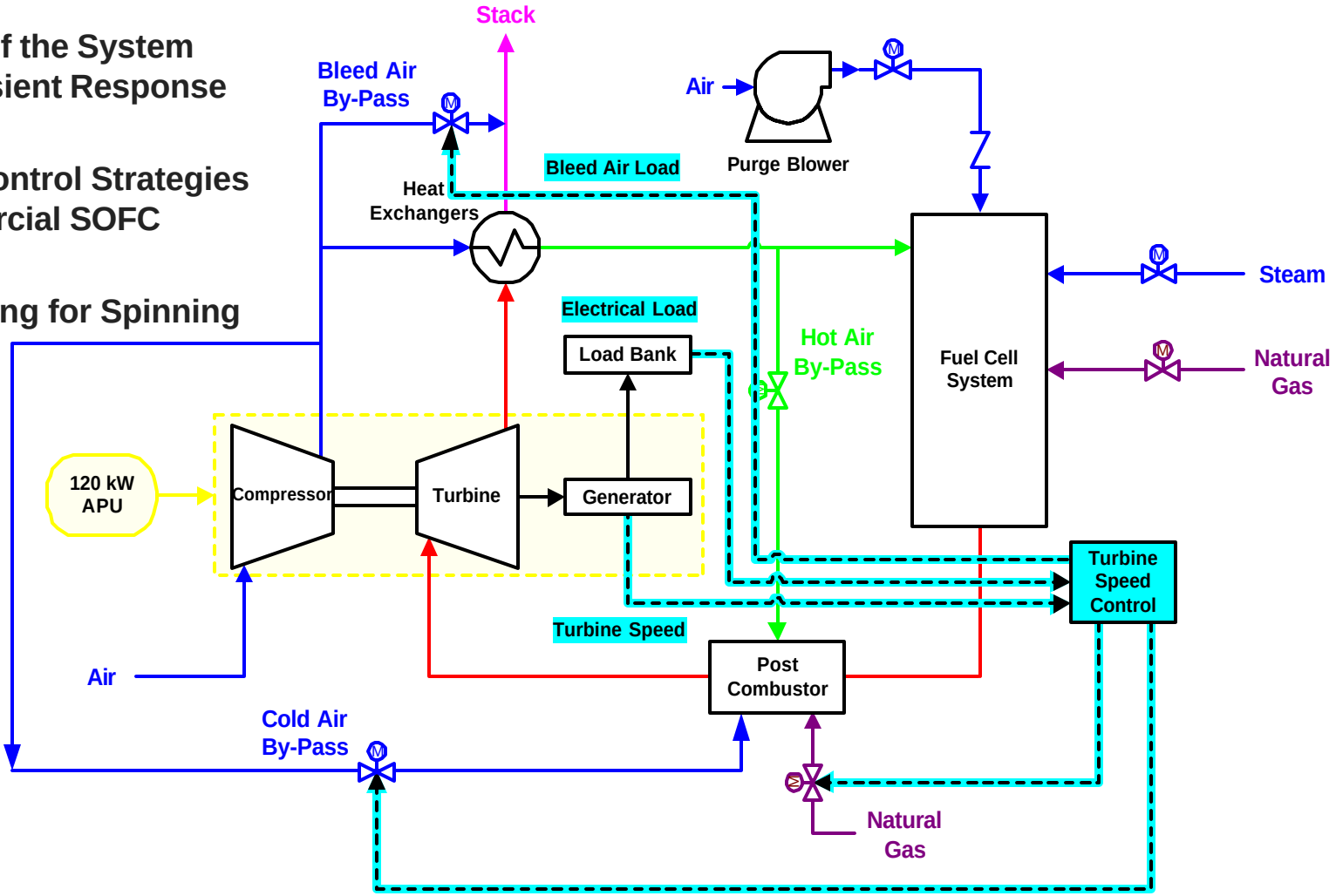
Research Plan- Phase III
Independent APU Speed Control and Load Following

- Secondary Combustion System for Independent APU Speed Control
- Load Following Evaluation and Impact
- Stall and Surge Dynamic Studies



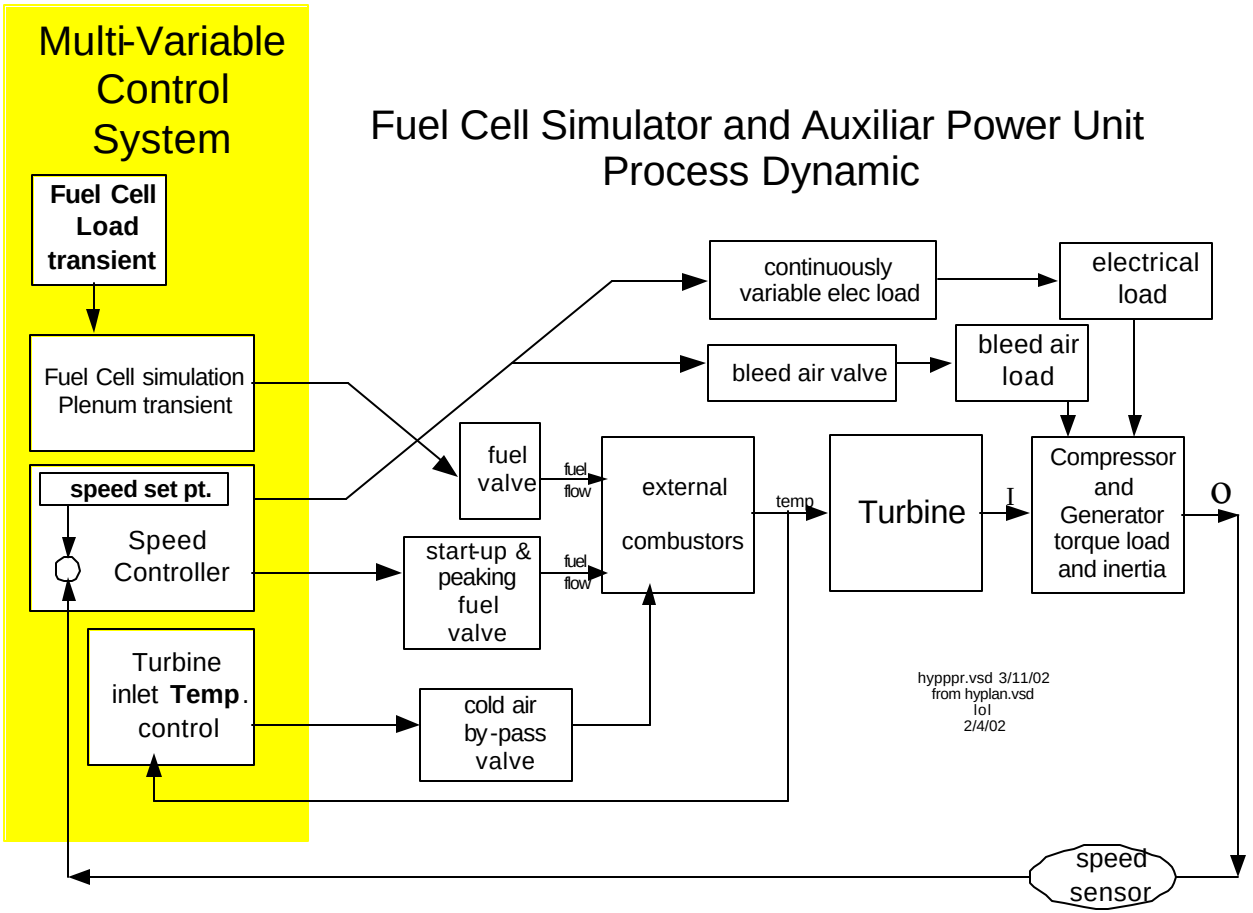
Research Plan- Phase IV
Integration of a Commercial Fuel Cell

- Operability of the System During Transient Response
- Testing of Control Strategies with Commercial SOFC
- Auxiliary Firing for Spinning Reserve



Control System Evaluation:

Mitigating Cross Purposes



References

1) Liese, E., R. S. Gemmen, F. Jabbari, and J. Brouwer (1999), "Technical Development Issues and Dynamic Modeling of Gas Turbine and Fuel Cell Hybrid Systems," 1999 ASME Turbo Expo, Indianapolis, IN (99-GT-360).

2) Liese, E. A. and R. S. Gemmen, "Transient Modeling Results of a Methane-Steam Prereformer," Presented at the Int. Mech. Eng. Congress and Exhibition, Nov. 5-10, 2000, Orlando Fl

3) Gemmen, R. S., E. Liese, J. G. Rivera, and J. Brouwer, "Development of Dynamic Modeling Tools for Solid Oxide and Molten Carbonate Hybrid Fuel Cell Gas Turbine Systems," 2000 ASME Turbo Expo, Munich, Germany.

4) Liese, E. A. and R. S. Gemmen, "Dynamic Modeling Results of a 1 MW Molten Carbonate Fuel Cell/Gas Turbine Power System," 2002 ASME Turbo Expo, Amsterdam, The Netherlands (GT-2002-30110).

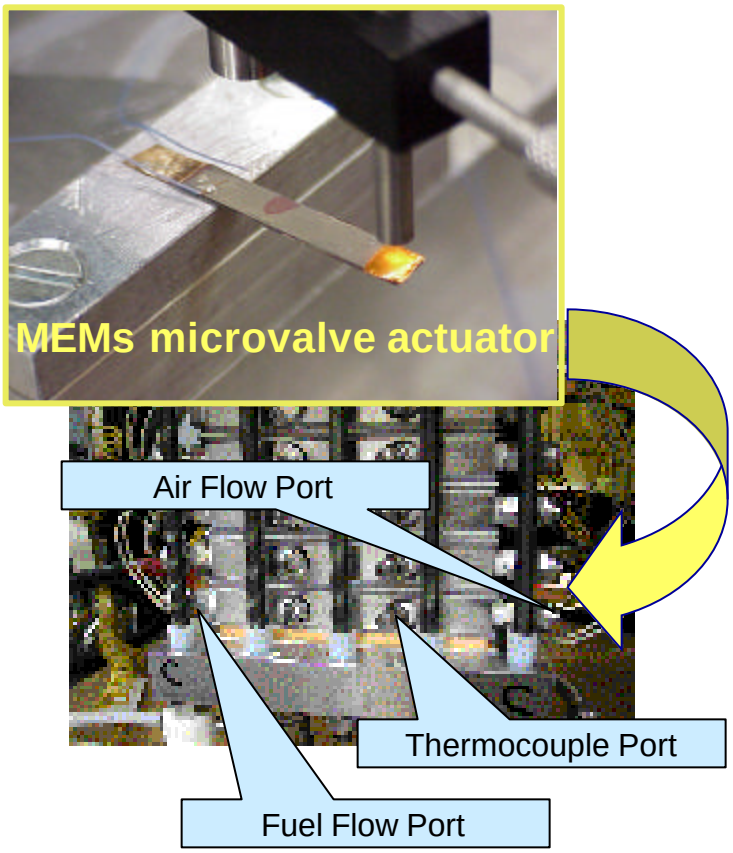
5) Liese, E. A. and R. S. Gemmen, "Performance Comparison of Internal Reforming Against External Reforming in a SOFC, Gas Turbine Hybrid System," 2003 ASME Turbo Expo, Atlanta, Georgia (GT-2003-38566).

6) Roberts, R.A., F. Jabbari, J. Brouwer, R. S. Gemmen and E. A. Liese, "Inter-Laboratory Dynamic Modeling of a Carbonate Fuel Cell for Hybrid Application", 2003 ASME Turbo Expo, Atlanta, Georgia (GT-2003-38774).

7) Tucker, D., E. Liese, J. VanOsdol, L. Lawson and R. Gemmen, "Fuel Cell Turbine Hybrid Simulation Facility Design," To be presented at the 2002 ASME International Mechanical Engineering Congress & Exposition.

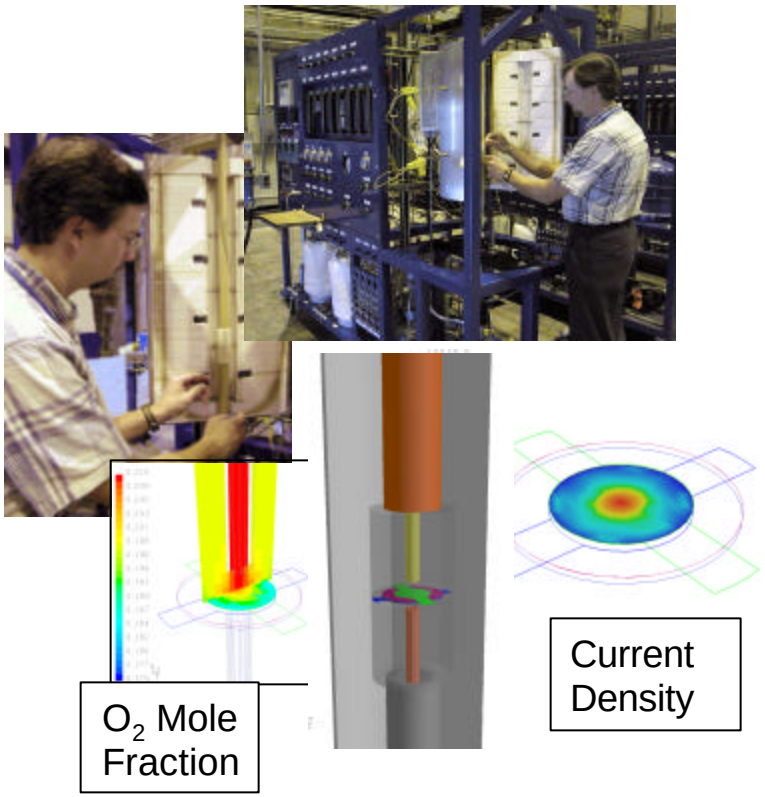
Related NETL Fuel Cell Research

Development of MEMs distributed oontrol
for PEM fuel cell flows
(with University of Pittsburgh)



Four cell PEM stack

Validation of predictive fuel cell models,
including dynamic current effects
(step & ripple loads).



SOFC test stands and simulations