Crosscutting Research

Session A8: Monitoring and Controls

April 11, 2019

NATIONAL ENERGY TECHNOLOGY LABORATORY

Advanced Controls and System Identification

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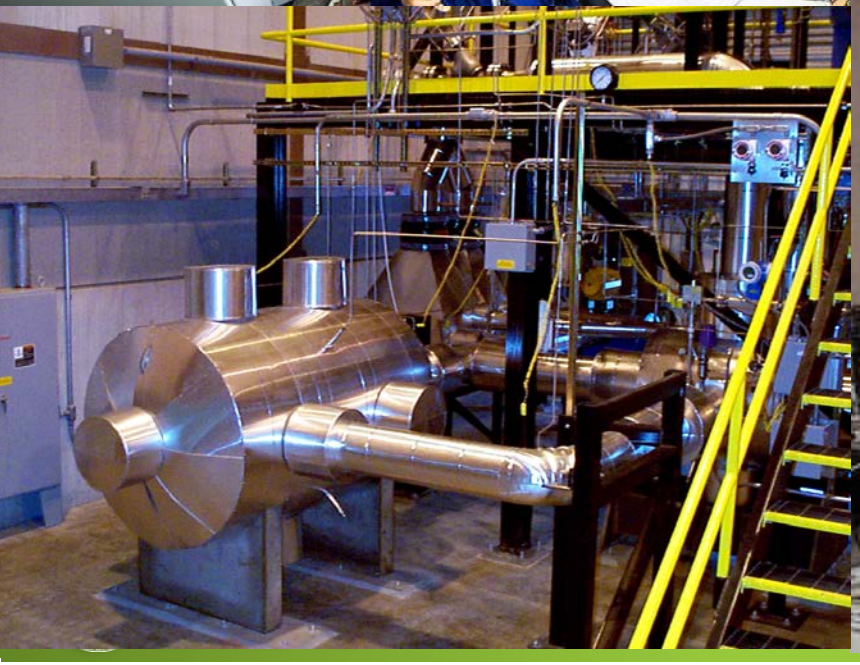
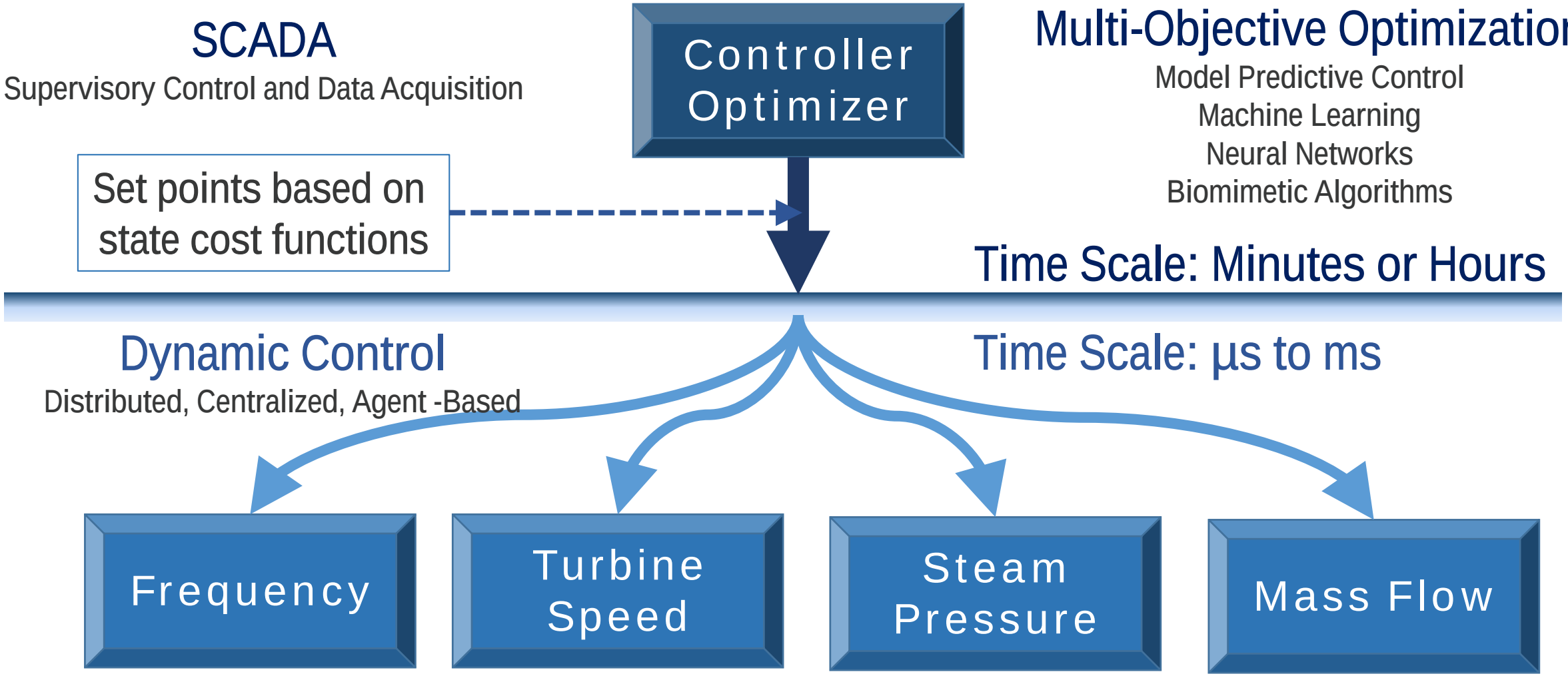
Solutions for Today | Options for Tomorrow

U.S. DEPARTMENT OF ENERGY

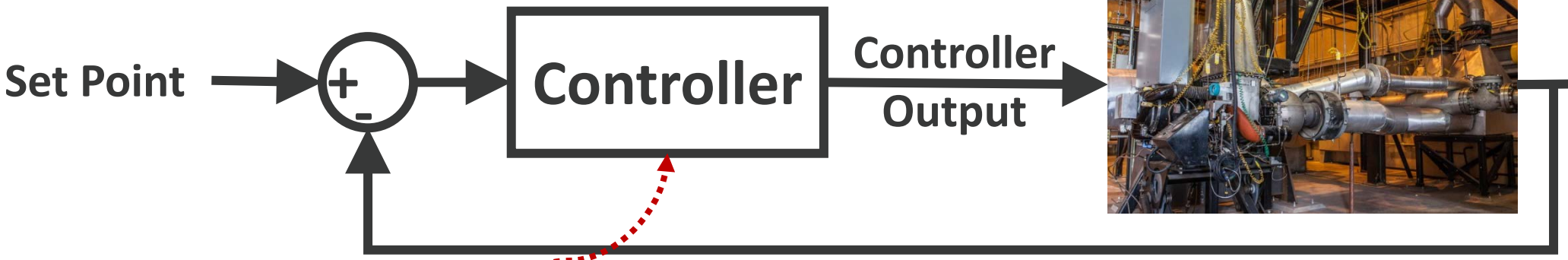
Hyper Gang



Controls, Models, and System Identification



Dynamic Control (Distributed PID)



Stable at a single operating state

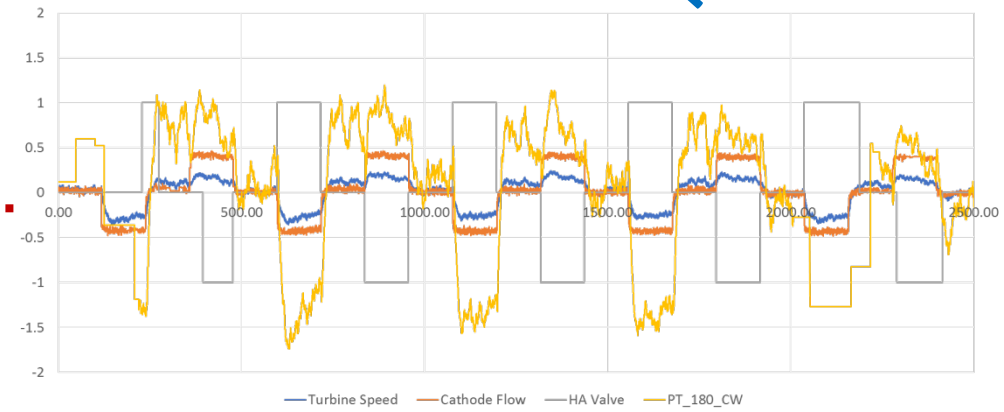
Gain Tuning

1st Order
Higher Order
Linear

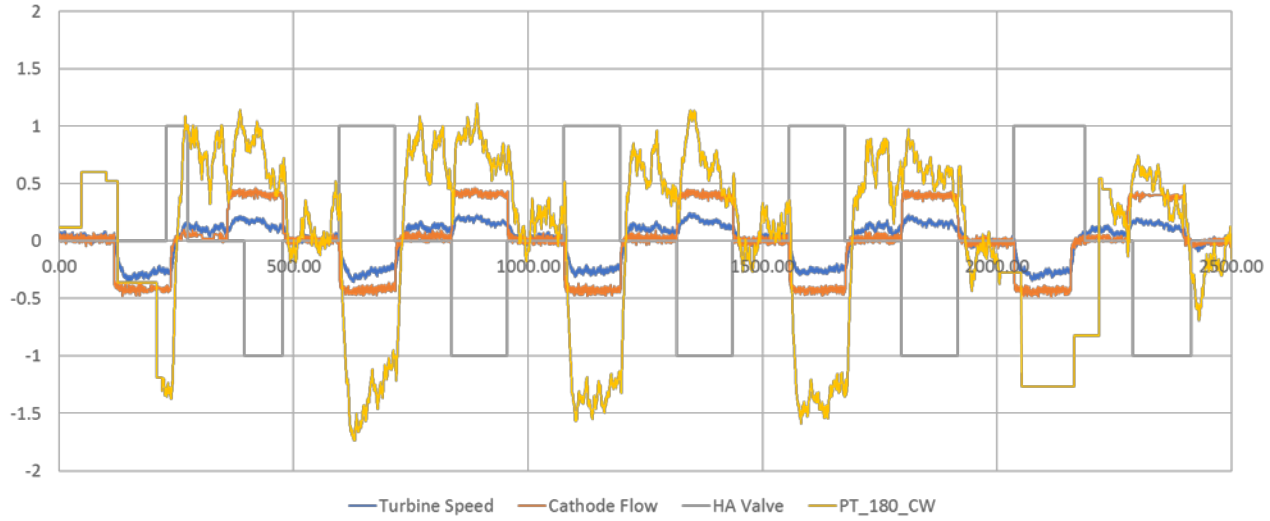
$$\frac{\omega_n^2}{s^2+2\zeta\omega_n s+\omega_n^2}$$

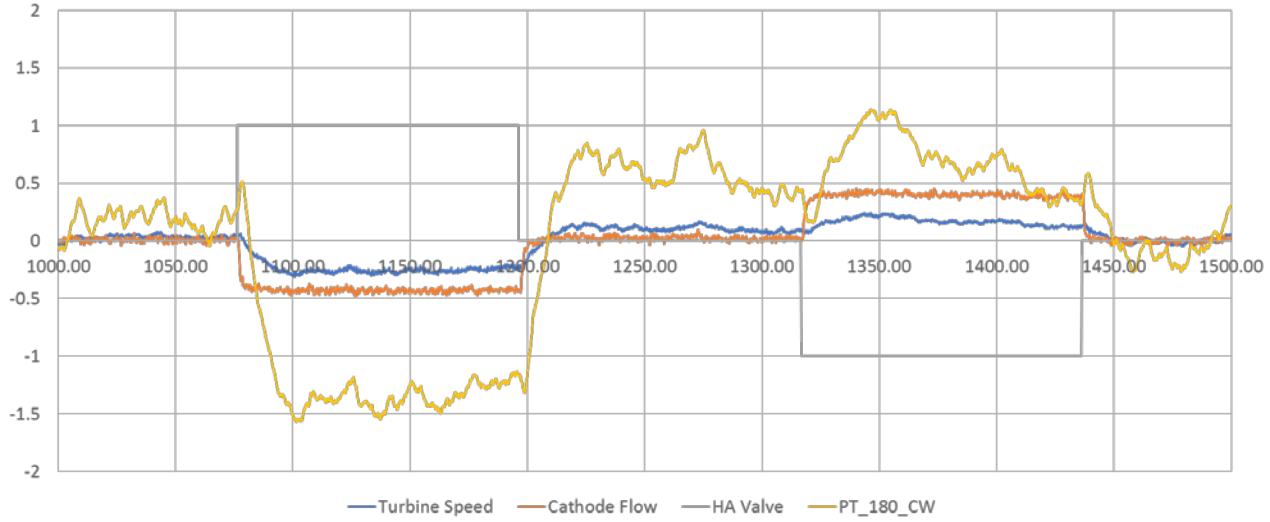
(Transfer function model)

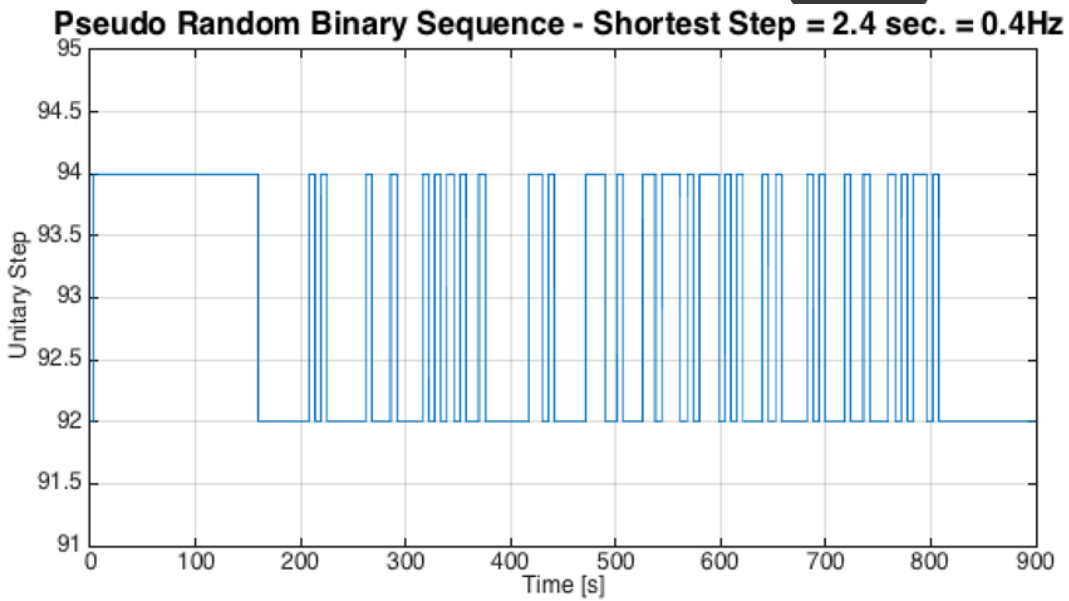
System Identification

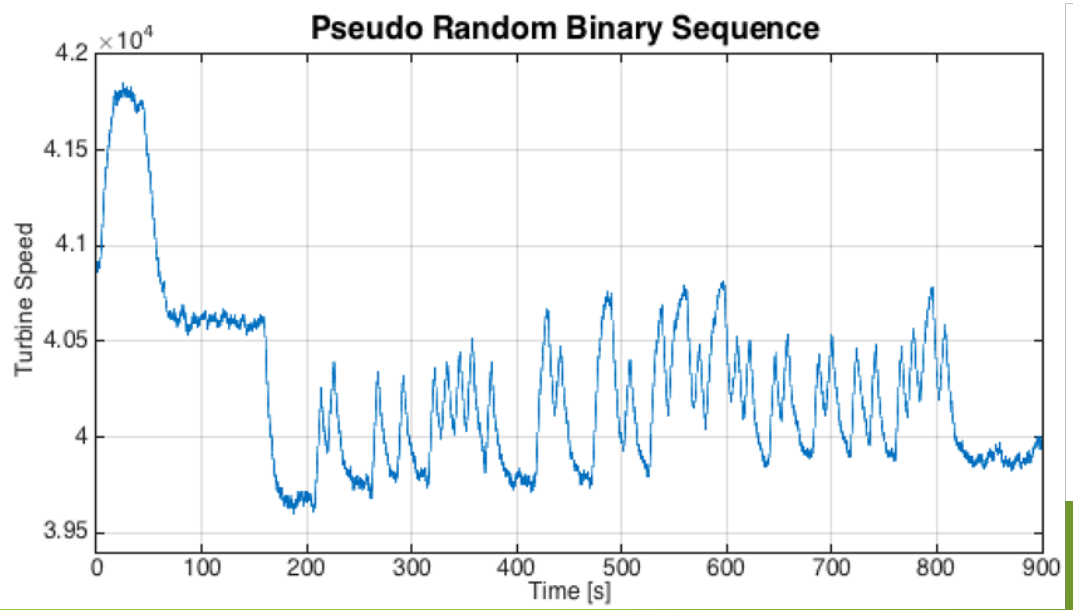


System Identification





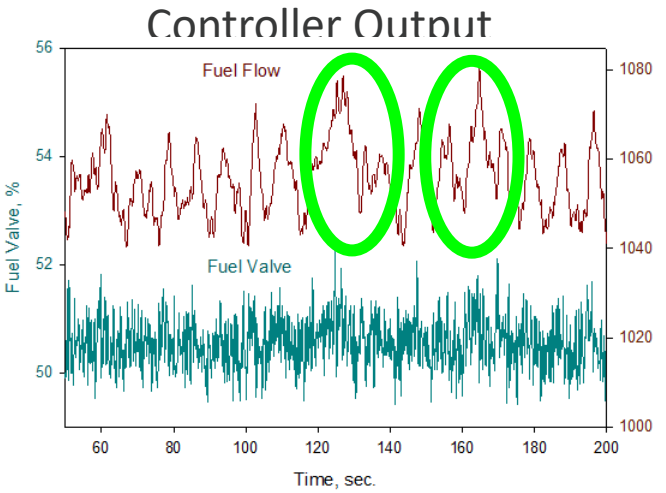


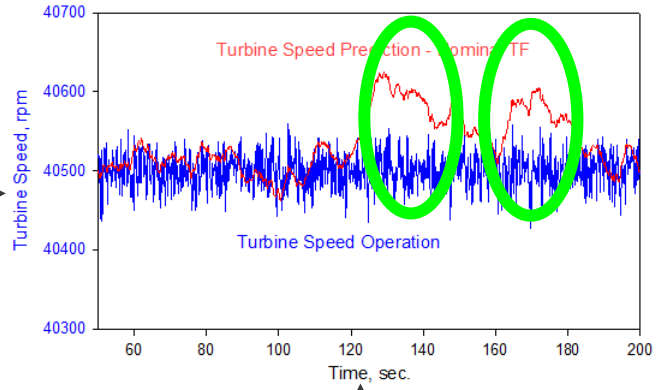


Online System Identification

Diagnostics

Set Point

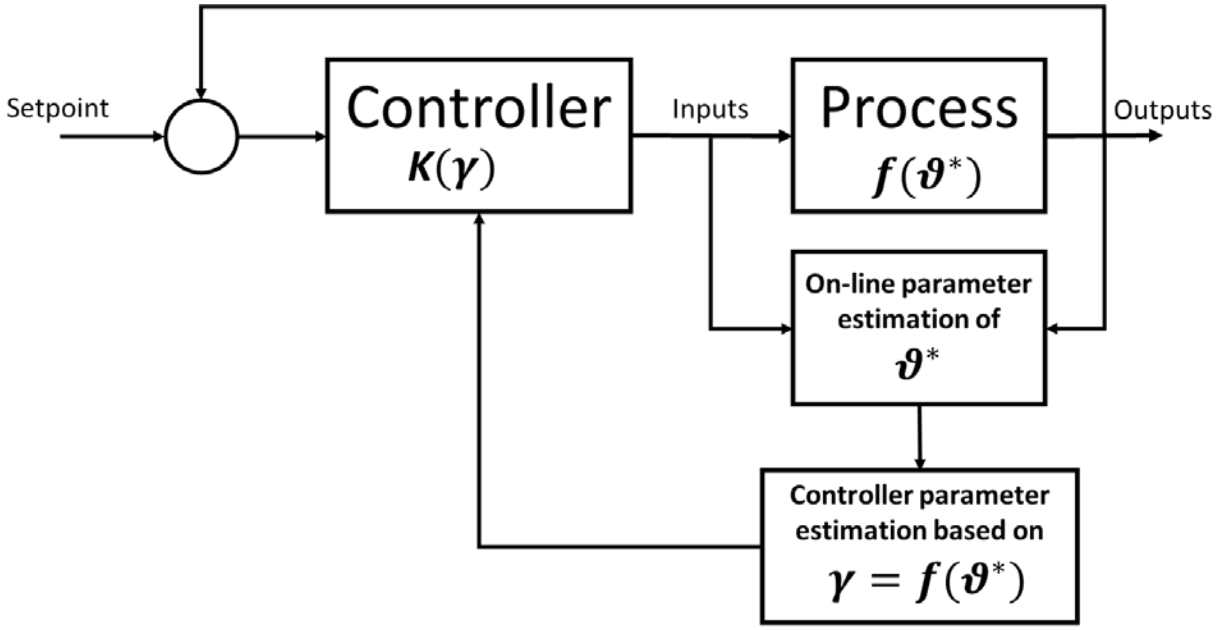


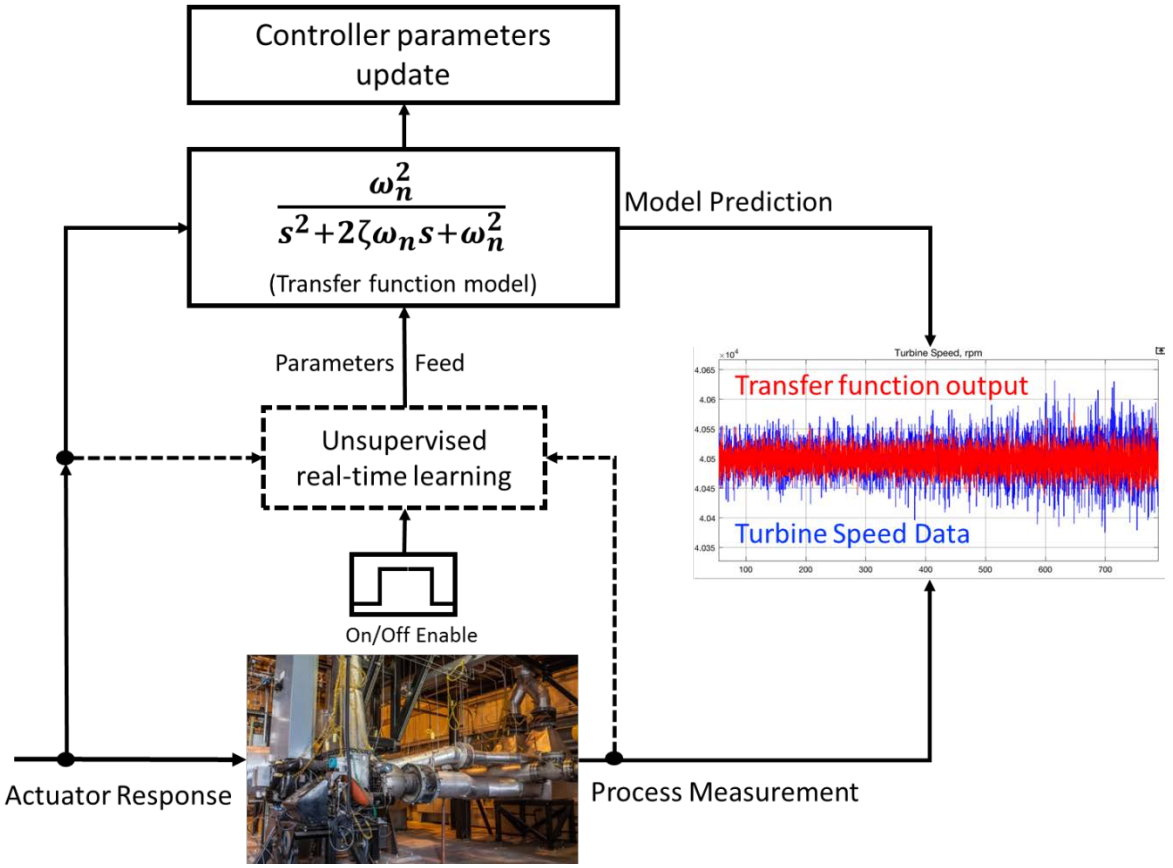


Transfer function at nominal condition

Continuously Adaptive Gain Scheduling

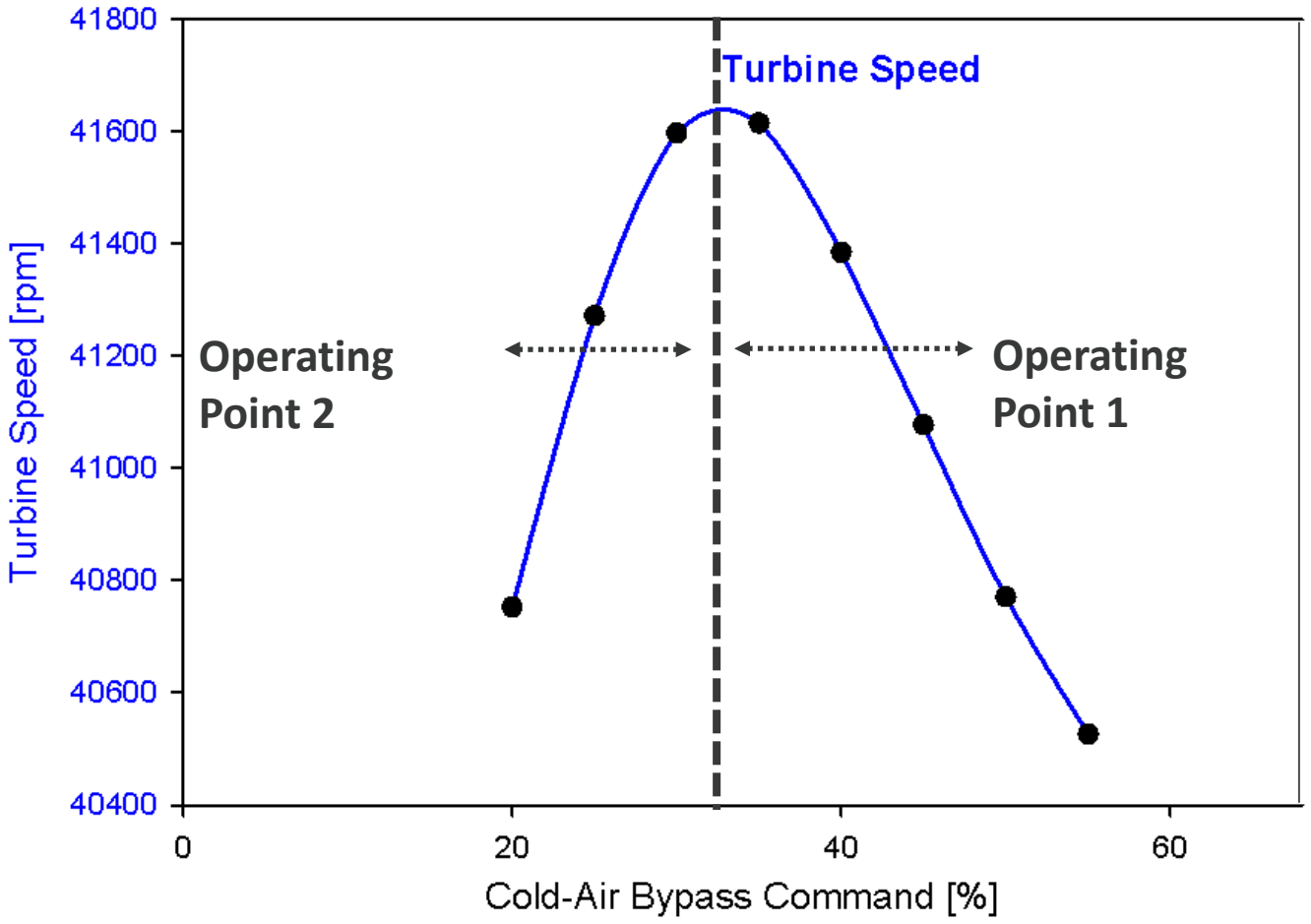
Online System Identification



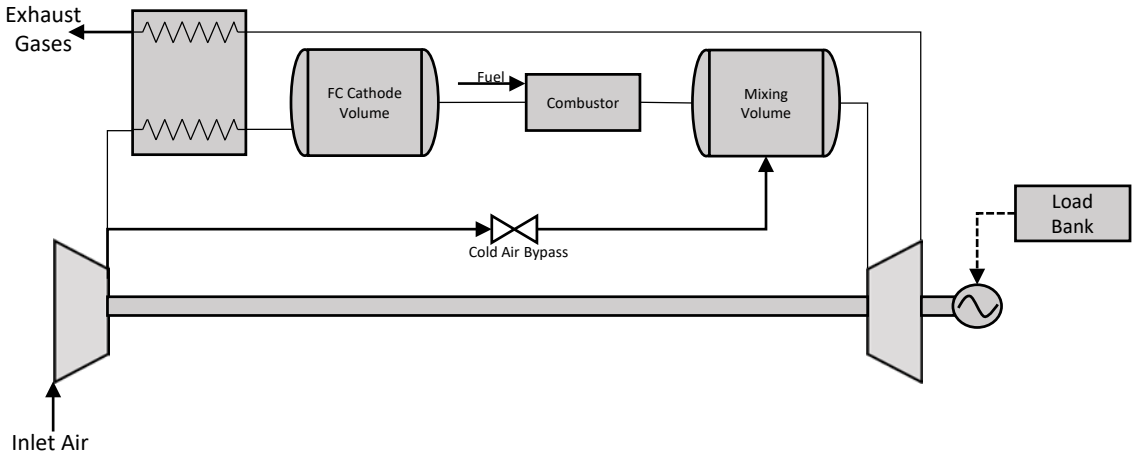


Continuously Adaptive Gain Scheduling

Coupling and Non-Linear Interactions

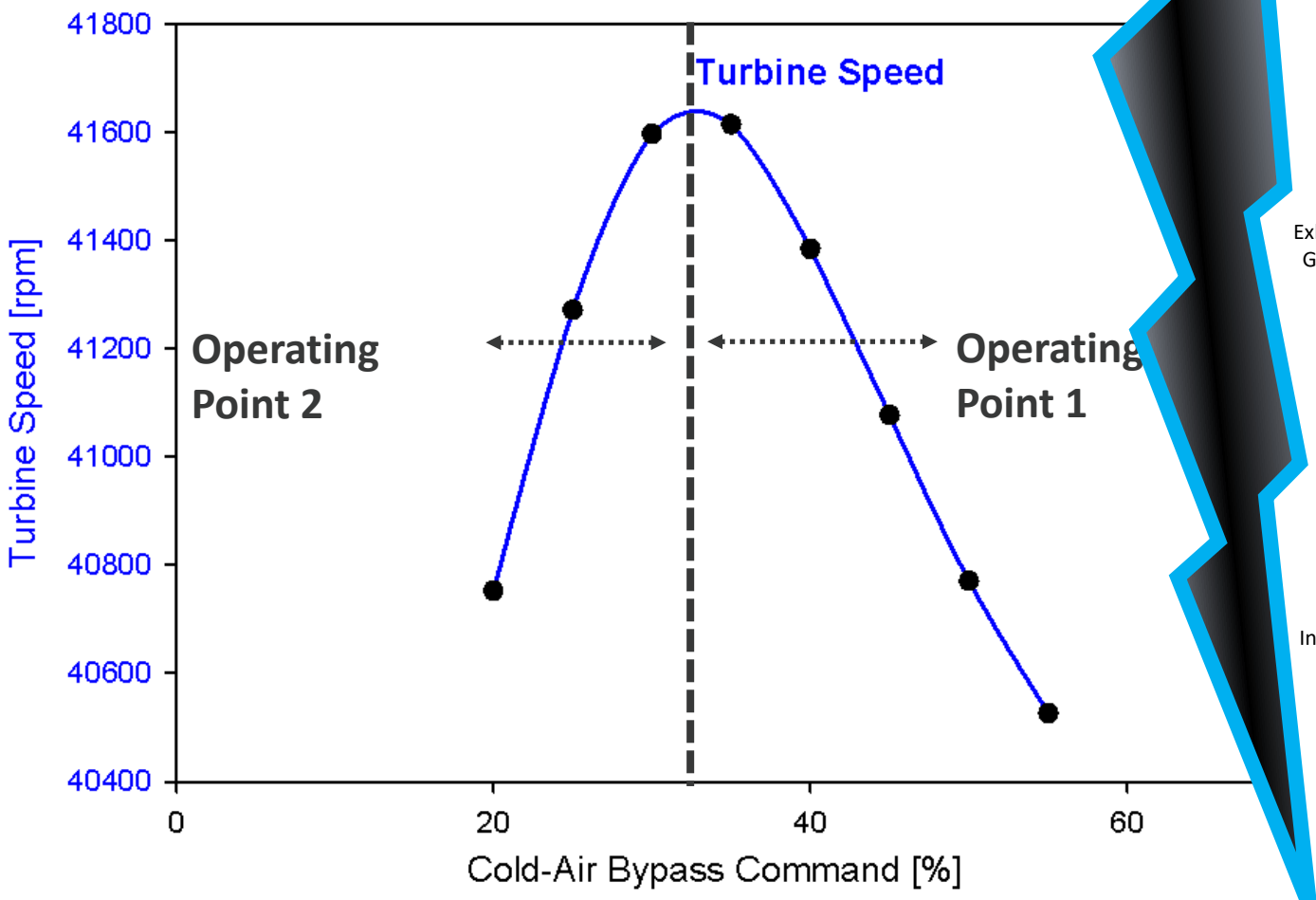


Non-Linear System Identification with Gain Scheduling

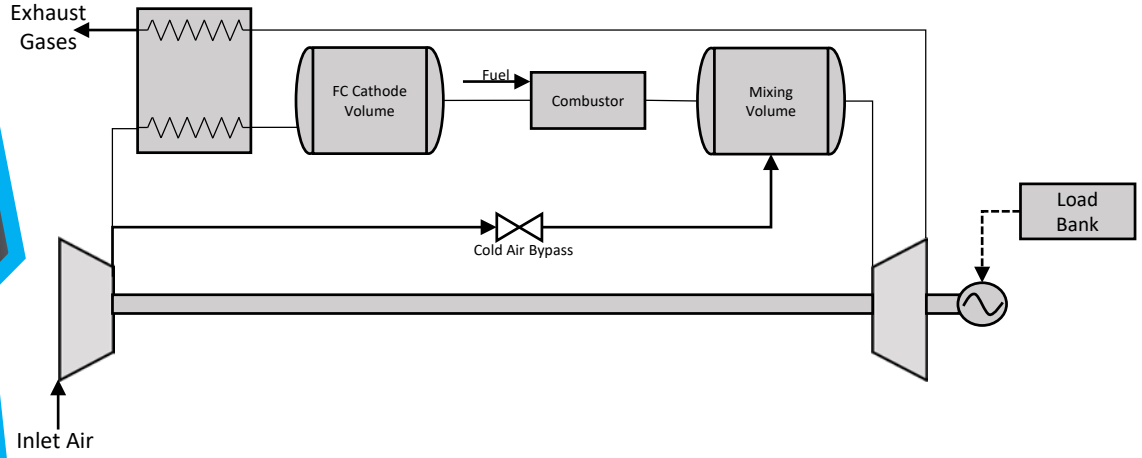


But…

Approach for Highly Coupled Systems

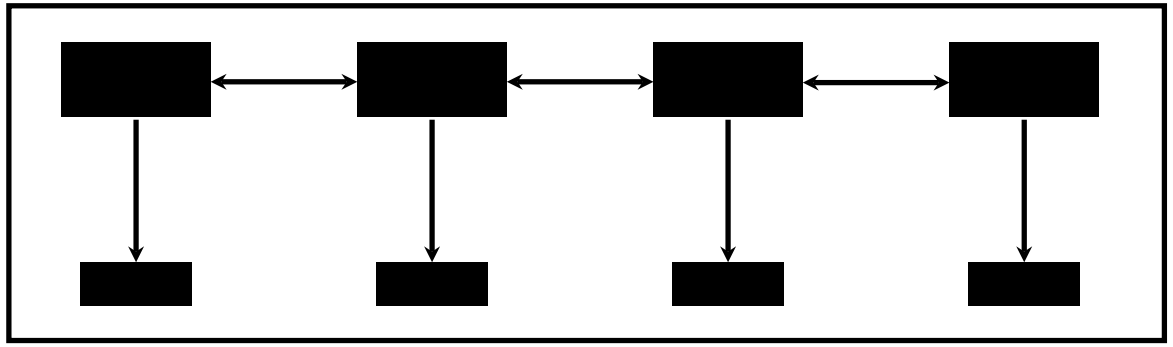


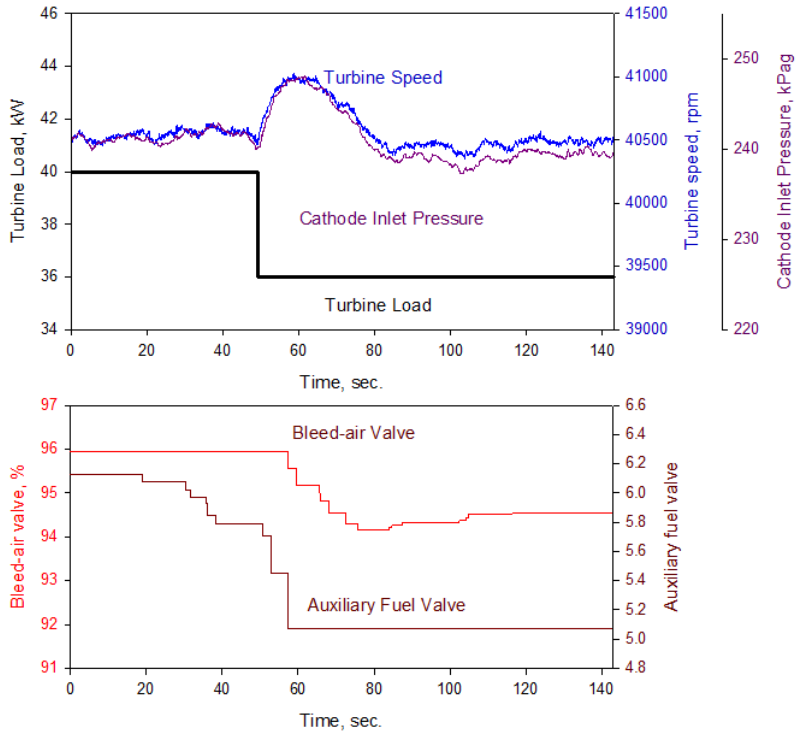
Physical Decoupling of the Process



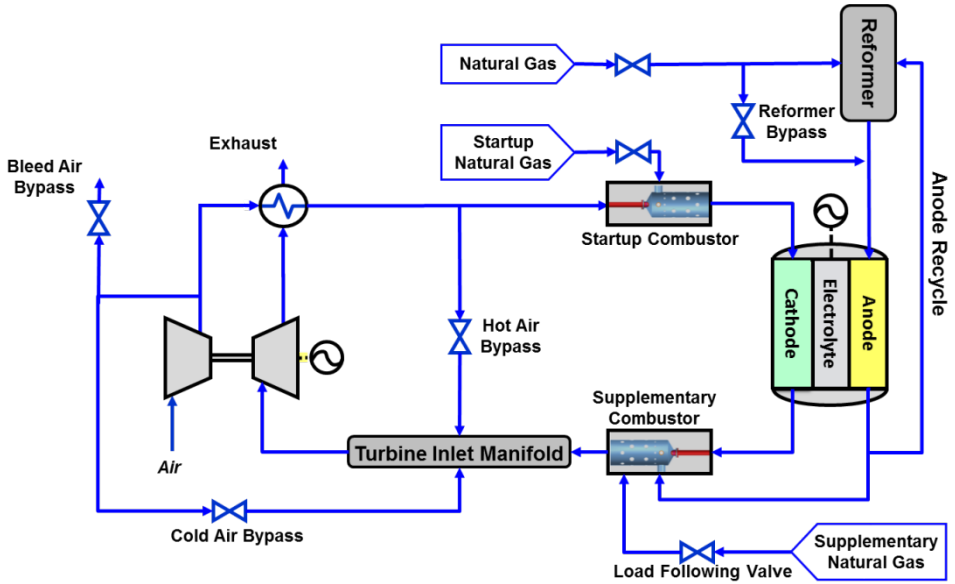
Current Paradigm for Technology Development

Model-Free Control (Agent-Based)

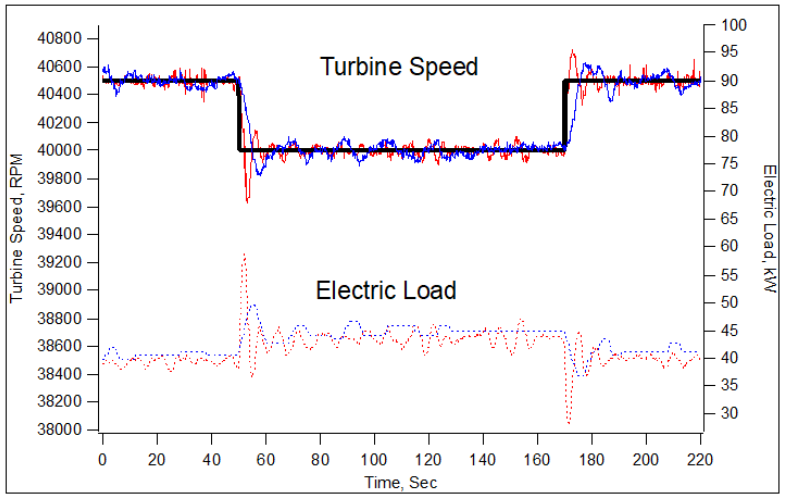


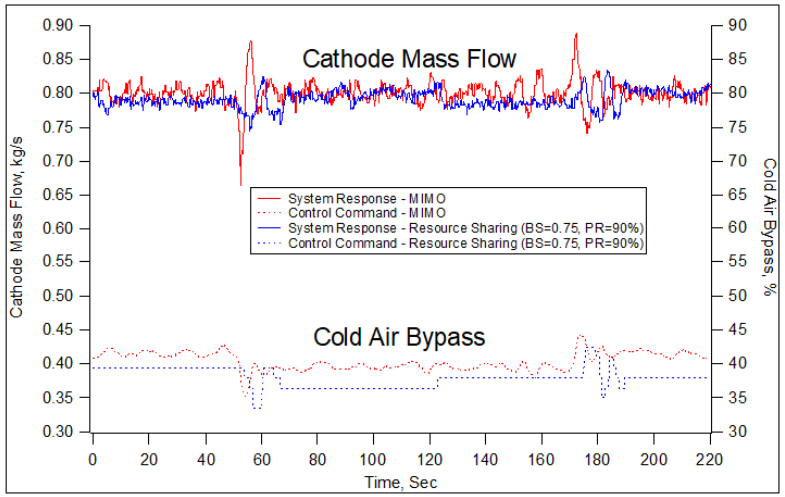


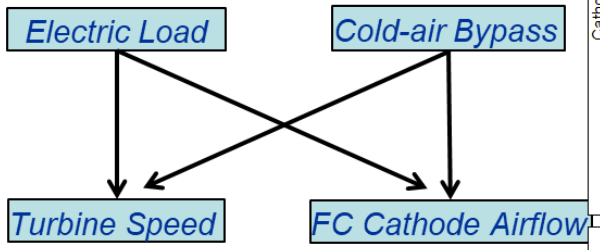
- Model-free design
- **Reconfigurable on different power plants**
- Multi-agents emulate intelligent control
- Agents can coordinate their behavior

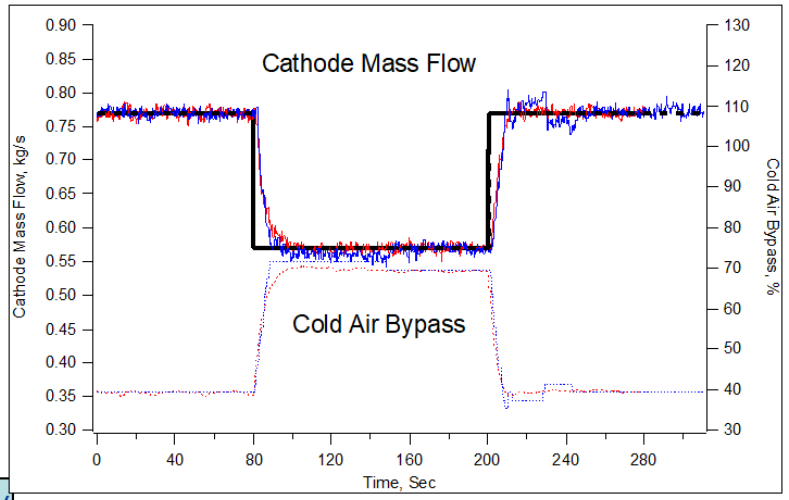


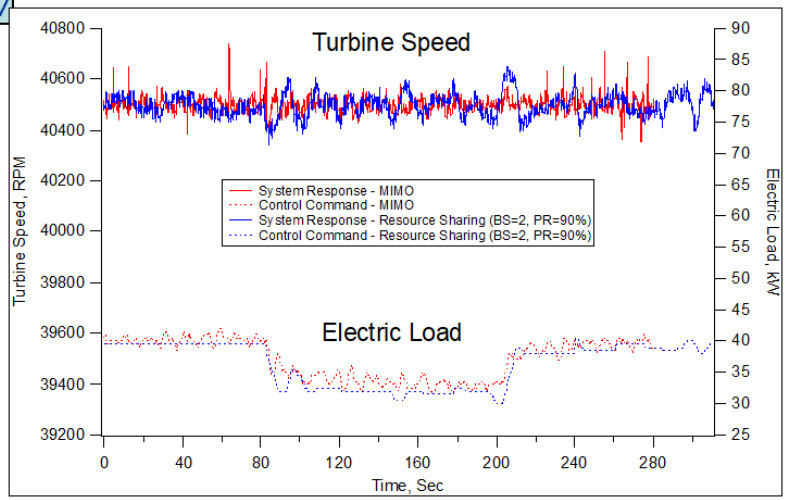
Airflow and Turbine Speed Control



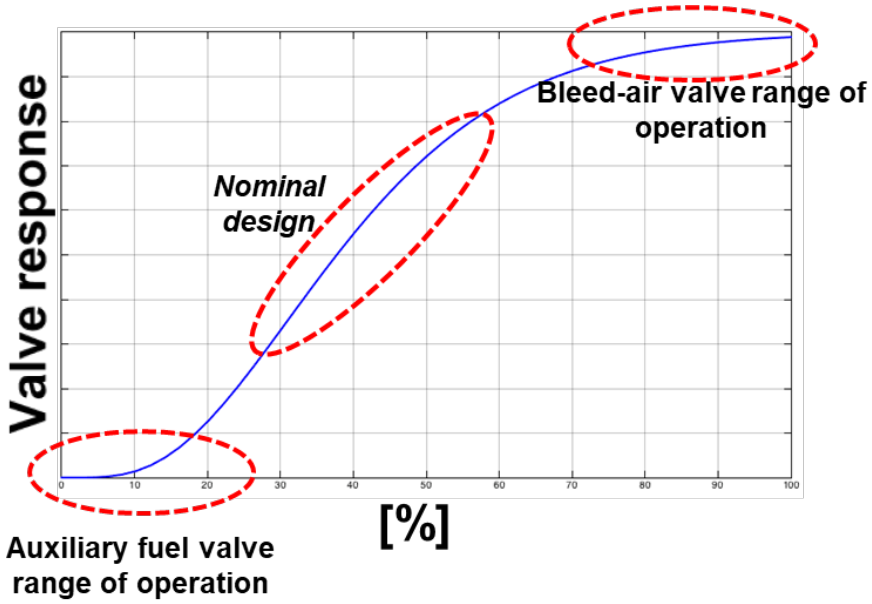


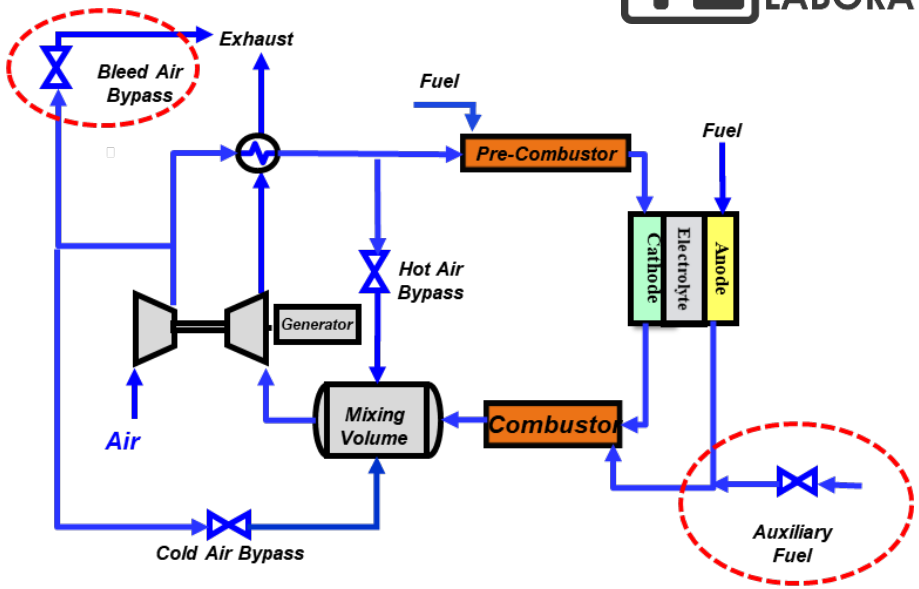






Load Following Control

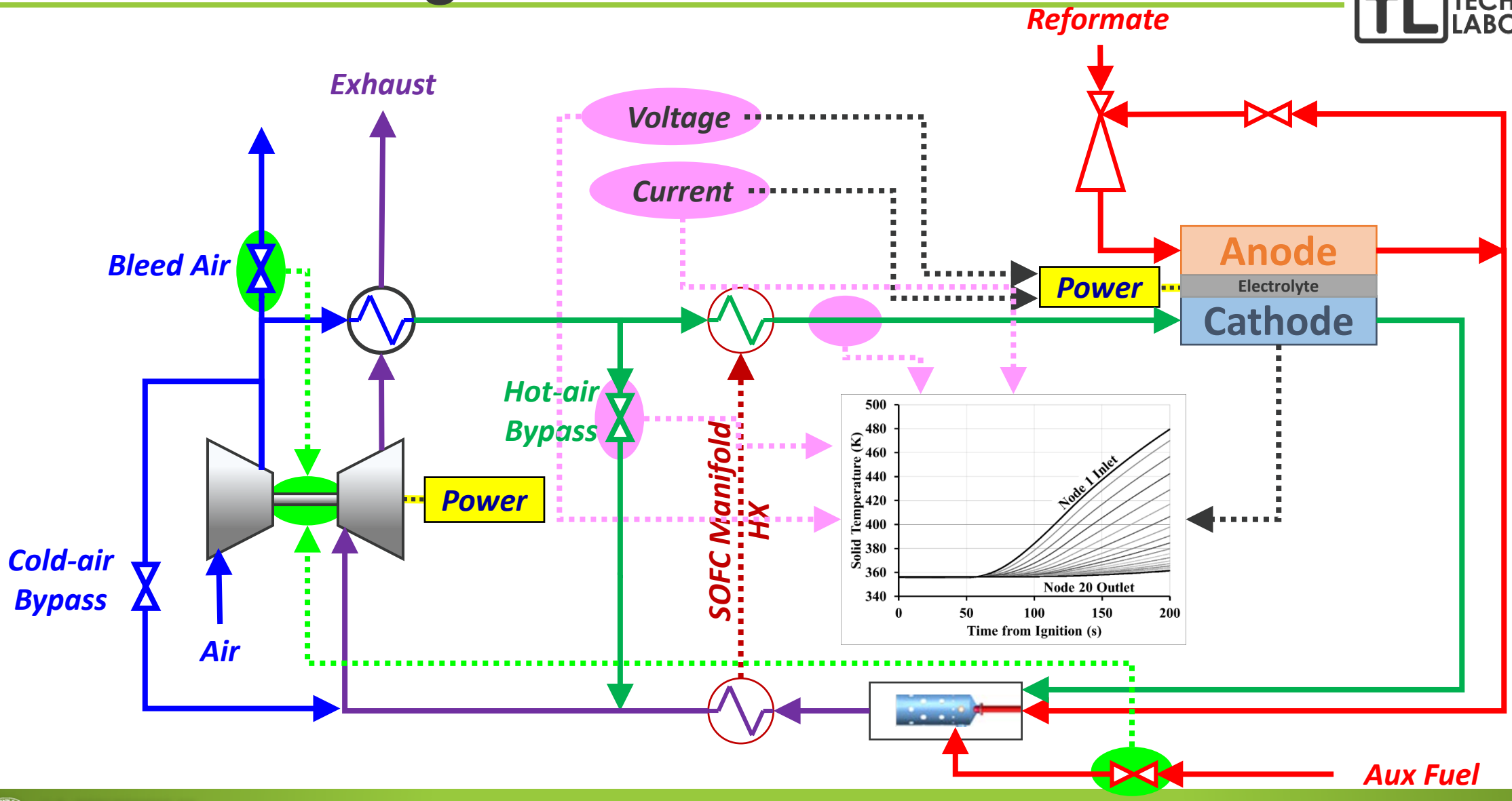




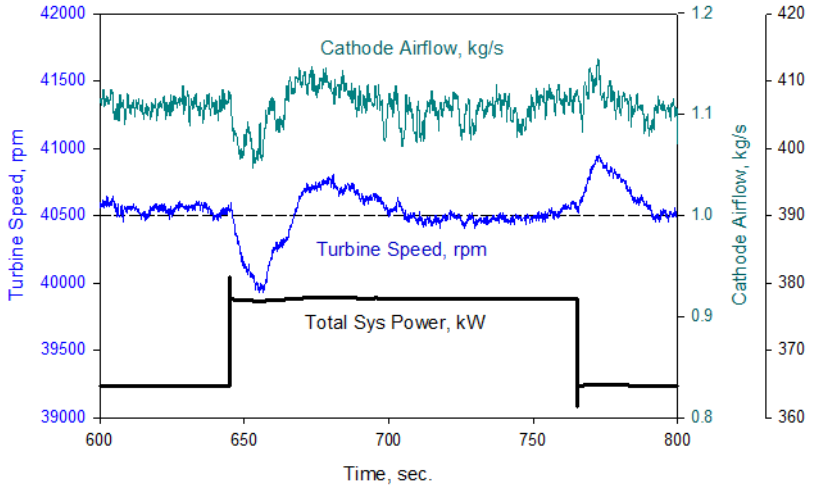
Nominal condition:

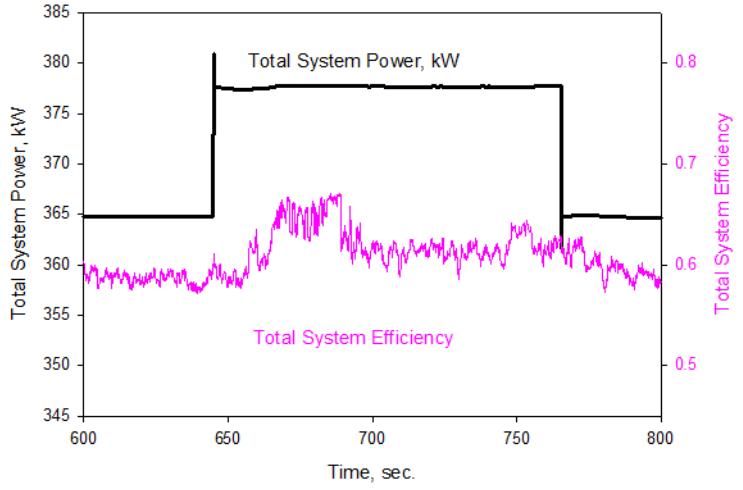
- Fuel cell thermal heat drives the gas turbine
- Closed valves position to maximize system efficiency
- Valve opening during transient operation

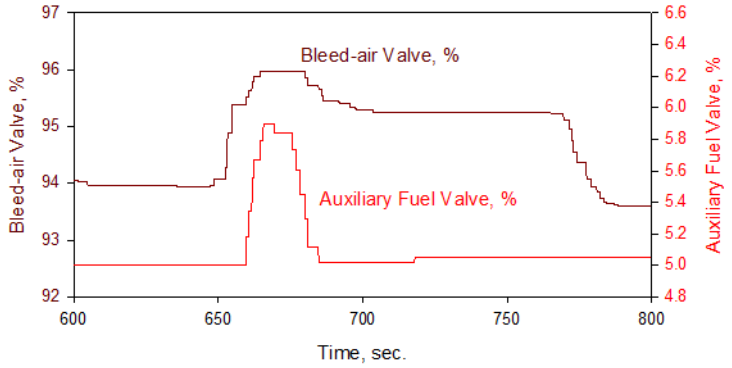
Load Following Control

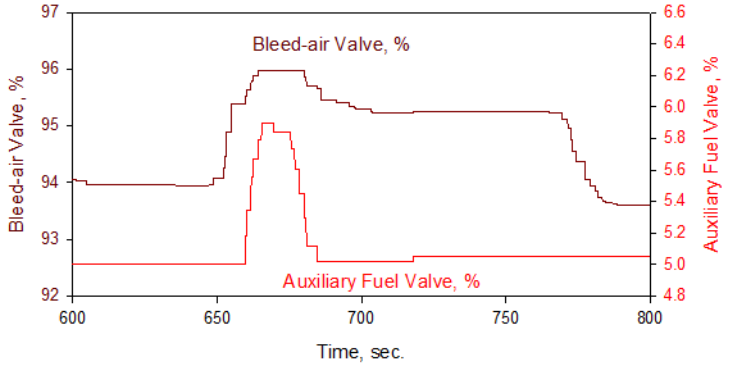


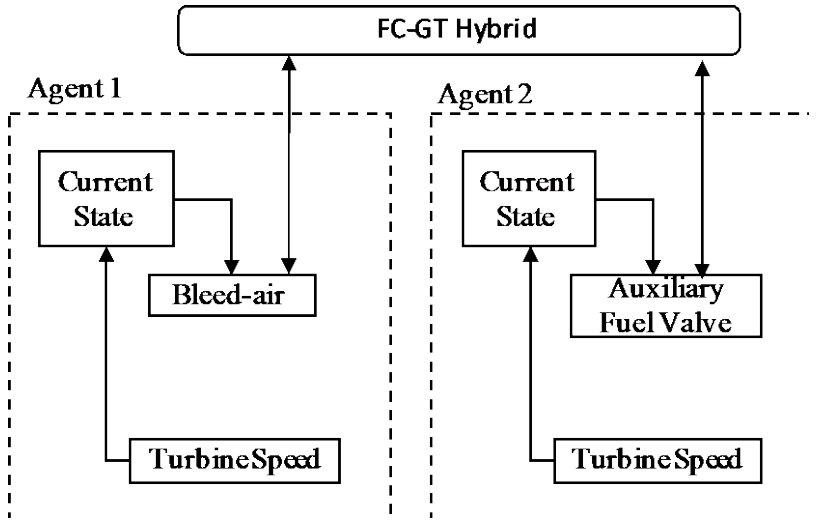
Load Following Control



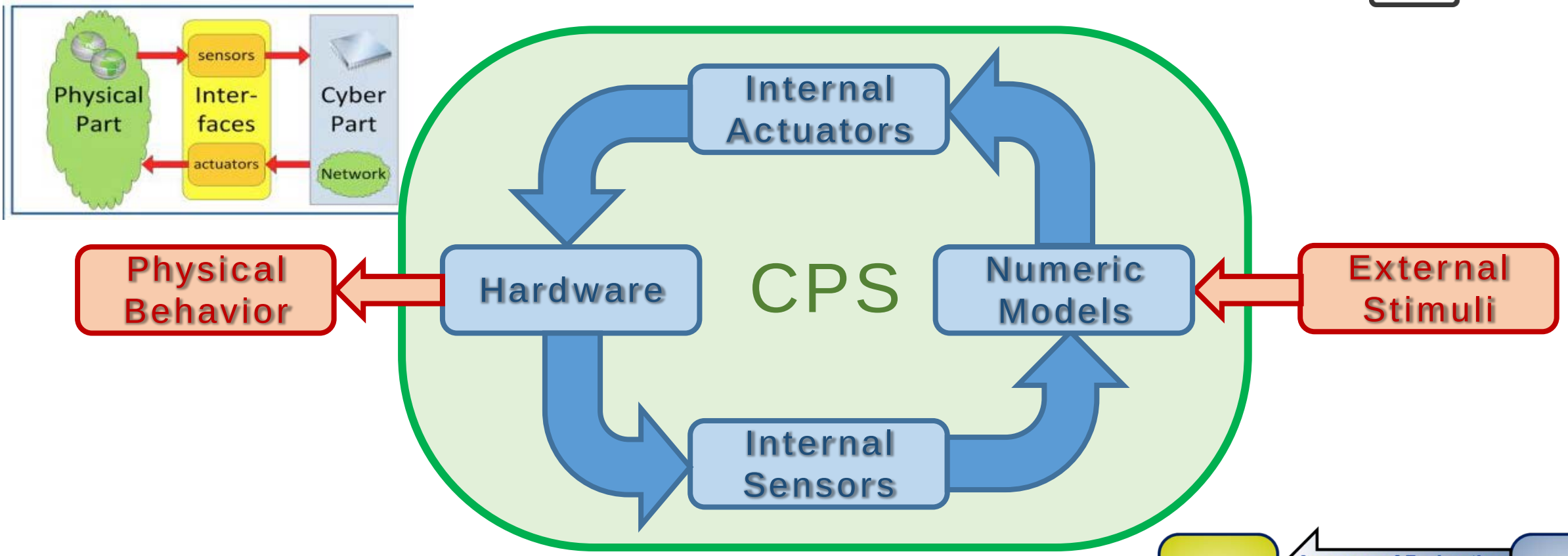






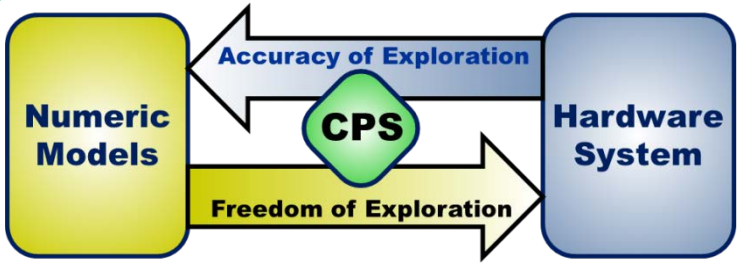


Cyber-Physical Systems

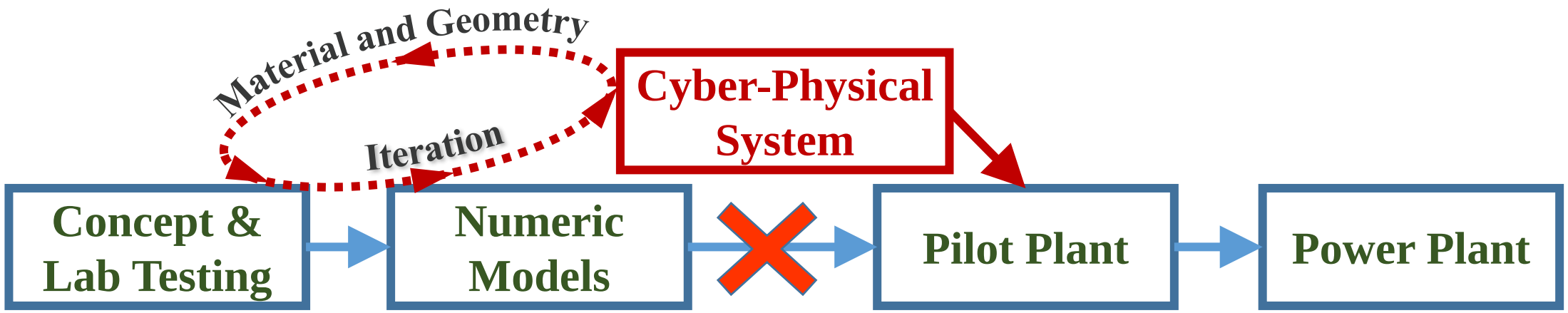


Cyber Physical Systems are used to replace physical systems that:

1. are irreplaceable,
2. are expensive,
3. can't meet performance targets.
4. don't exist…yet

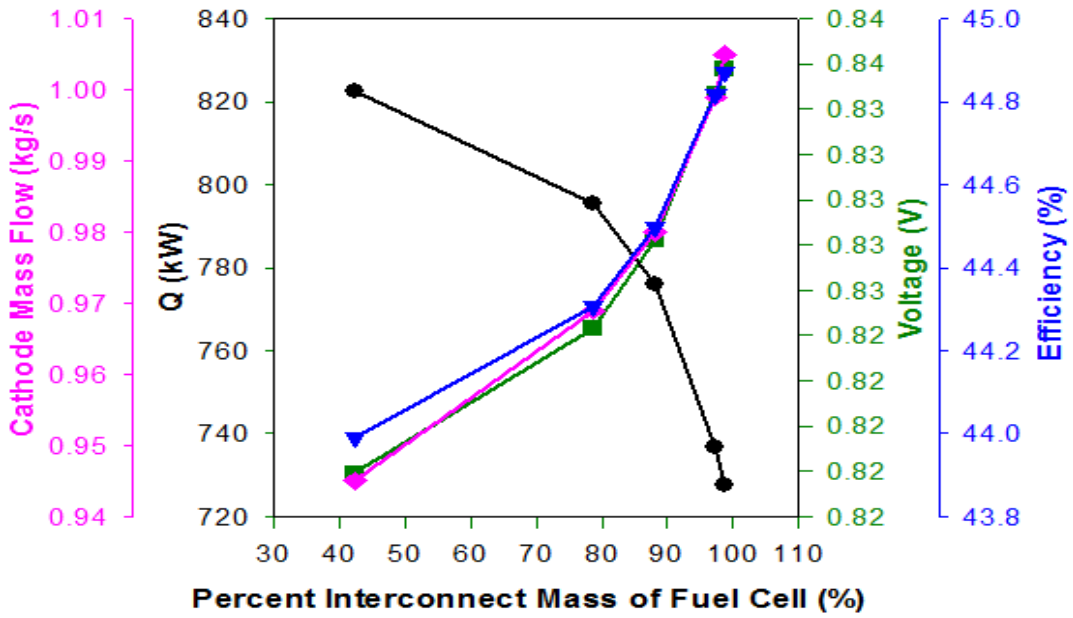


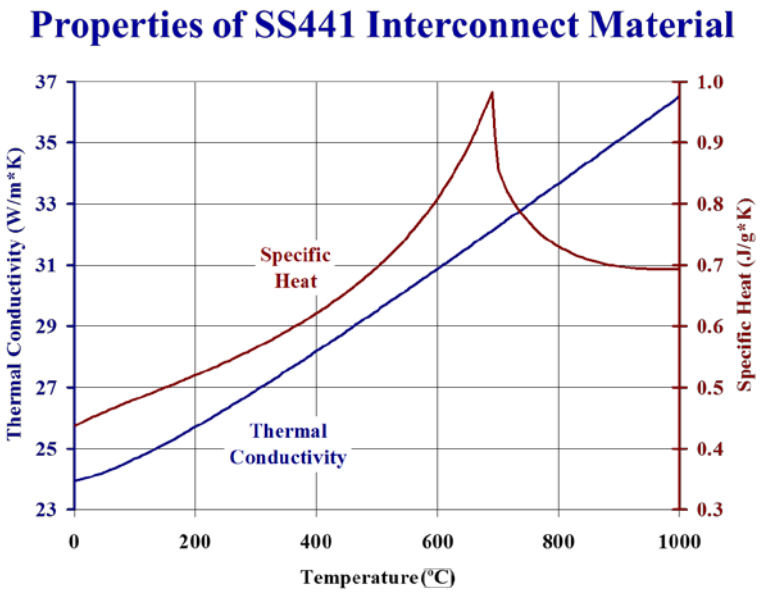
Technology Development

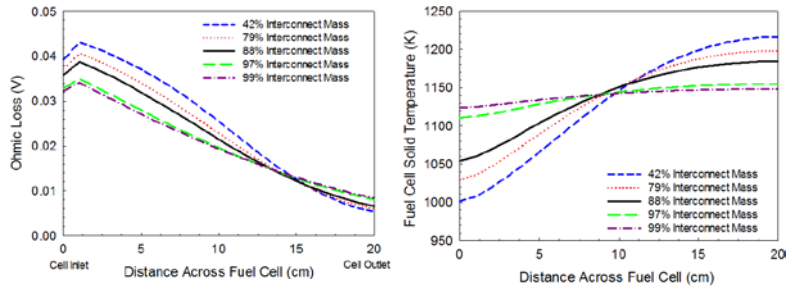


Technology Development

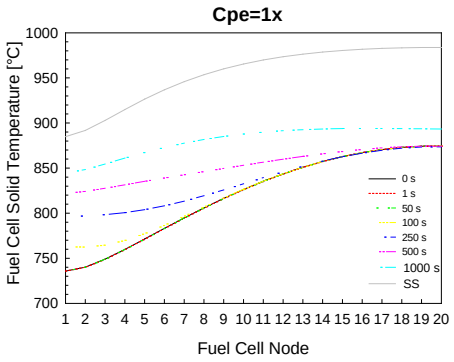
Example: TES in Hybrids for Load Following

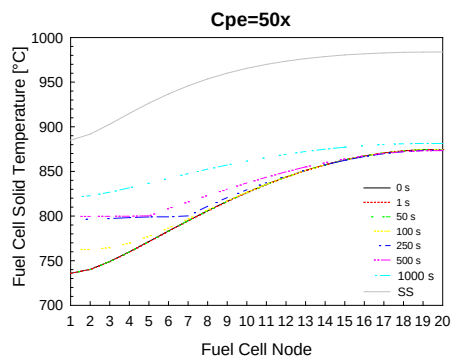






Higher system efficiency and load following without risk to the fuel cell





Sensor Fusion in Agent-Based Stigmergy

Future Steps:

- Multiple sensors in one agent to control unobservable or slow responding parameters.
- Multiple sensors coordinated by supervisory control.
- Accelerate the response of the MISO turbine speed control by modifying the probability of action and block size. Currently, we have achieved 2kW/s (4%/s) in the Hyper facility, but 4kW/s (8%/s) would be required to eliminate a battery in an islanded microgrid based on NETL's power usage.

Advanced Controls will Change the World!!!

Thank You

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