Control Strategies for an Integrated SOFC/GT System

NETL LEAP Workshop

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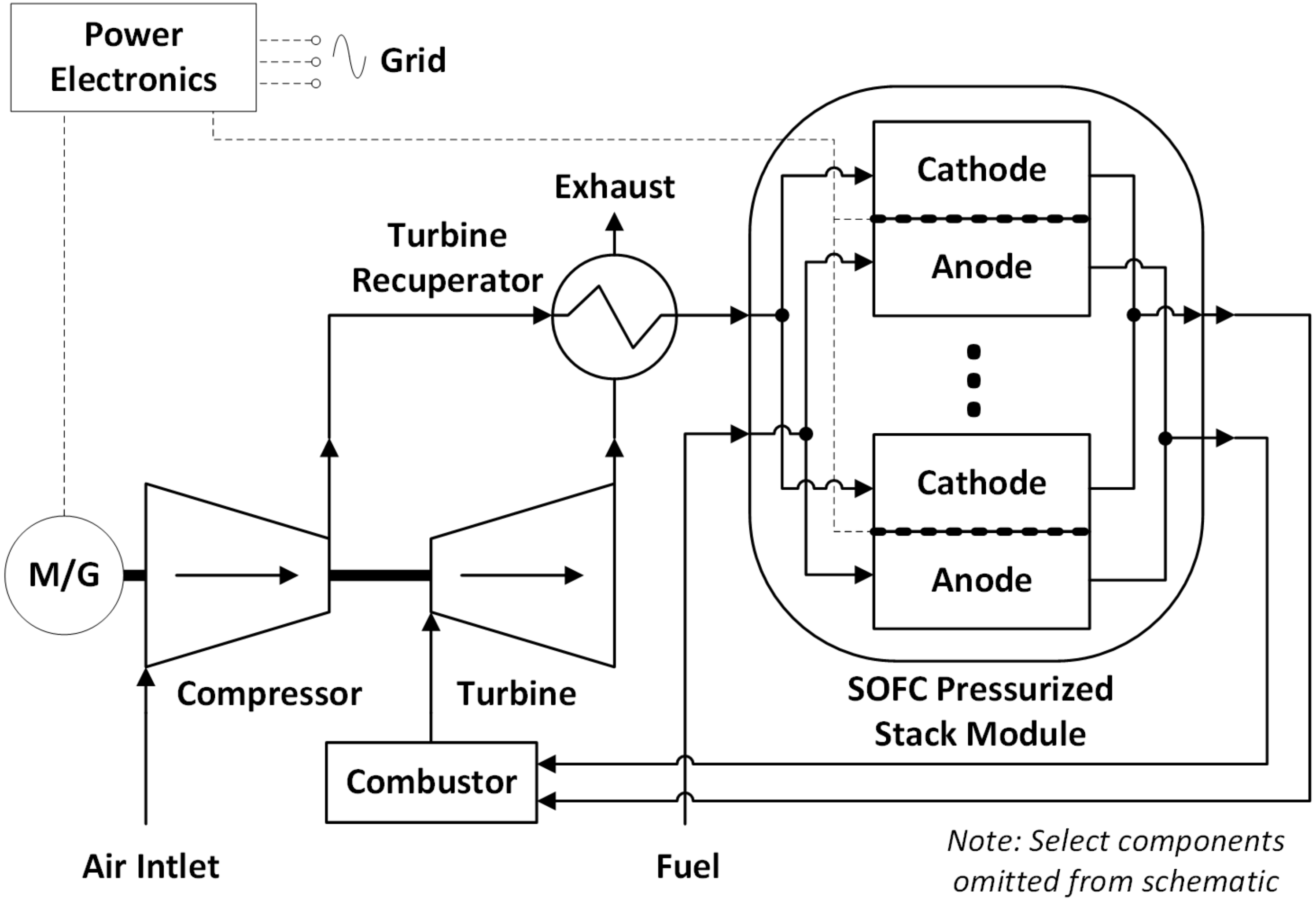
Solid Oxide Fuel Cell / Gas Turbine Hybrid System

arpa·e
CHANGING WHAT'S POSSIBLE

Supported through ARPA-E INTEGRATE project number DE-AR0000956

Project Targets:

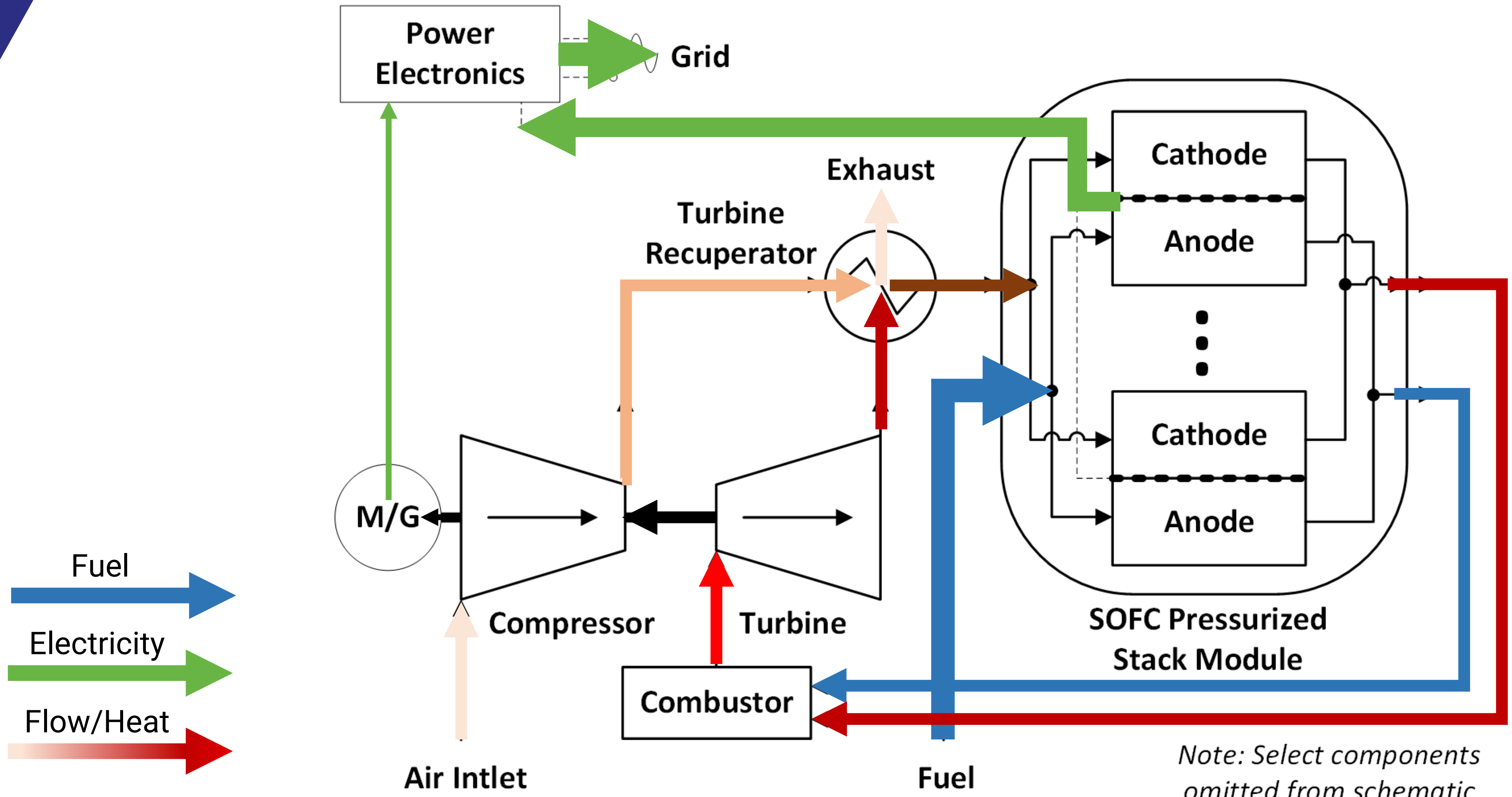
- SOFC/Turbine Hybridization
- Pressurized operation
- Natural gas fuel
- 70%+ LHV efficiency
- Installed Cost: $1800 per kW



Note: Select components omitted from schematic

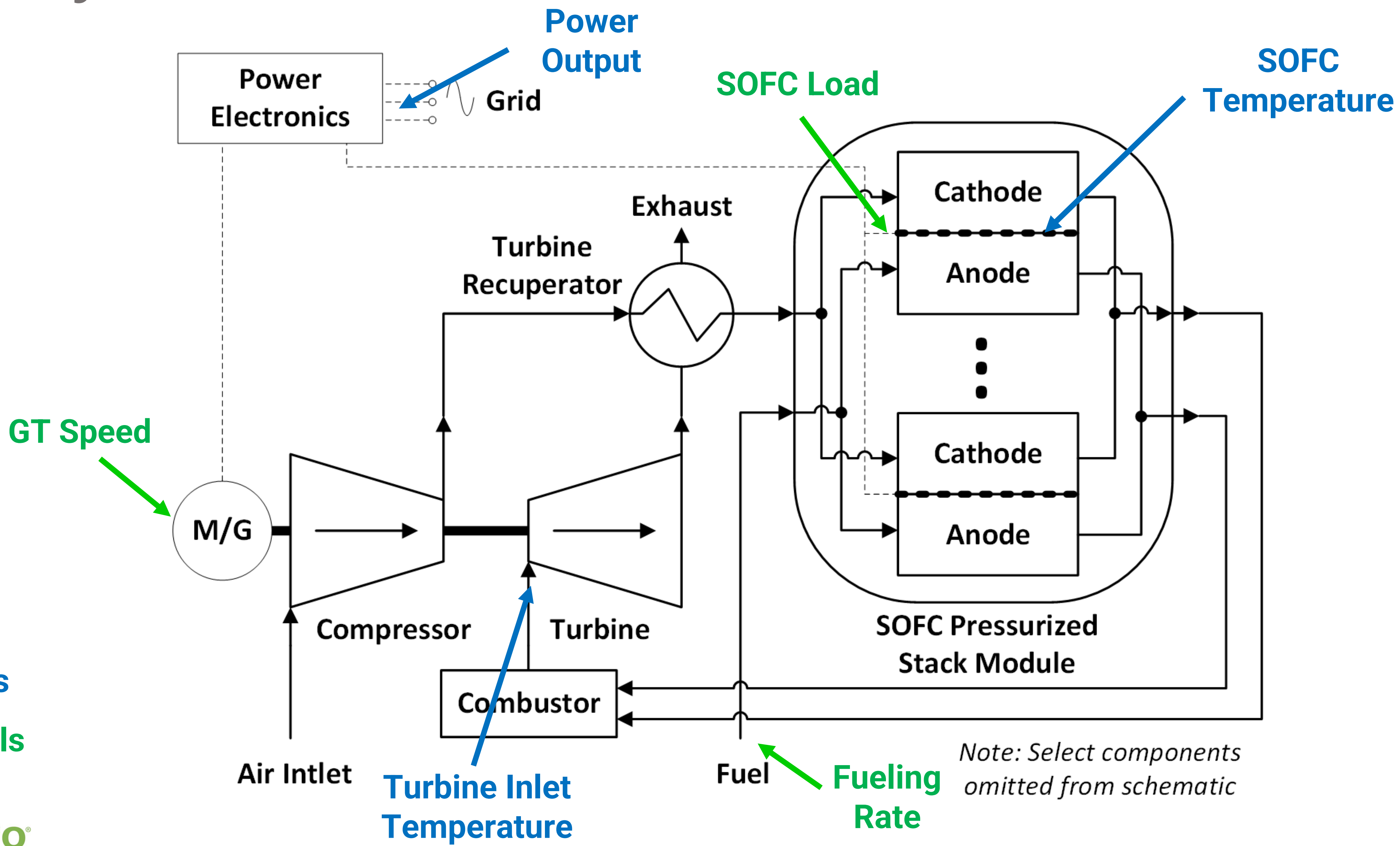
NEXCERIS where energy meets environment
Czero ENGINEERING TOMORROW
BraytonEnergy

Basis of Operation



Note: Select components omitted from schematic

Key States and Controls



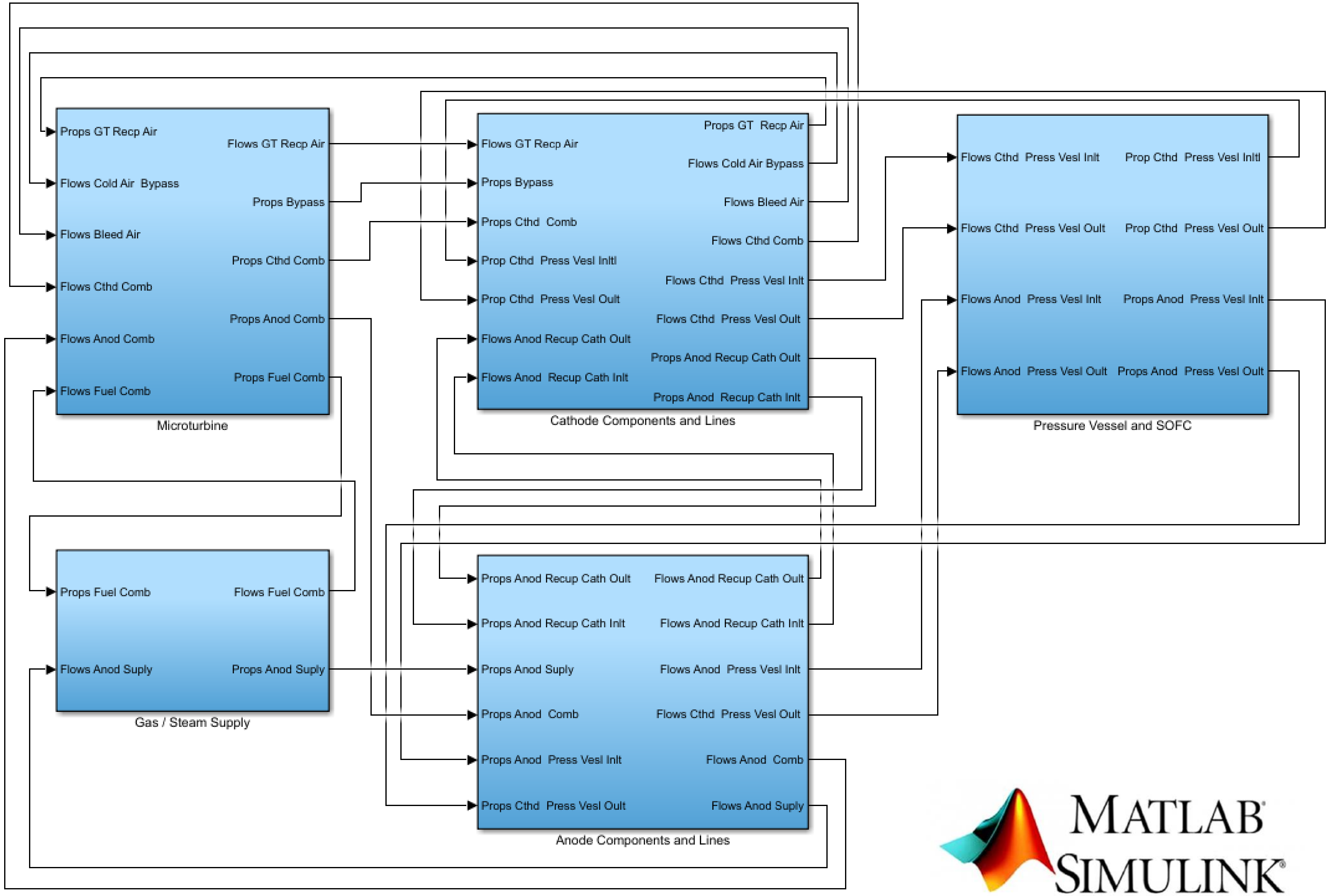
States

Controls

Dynamic System Model

All custom code built up from governing equations, built in MATLAB Simulink

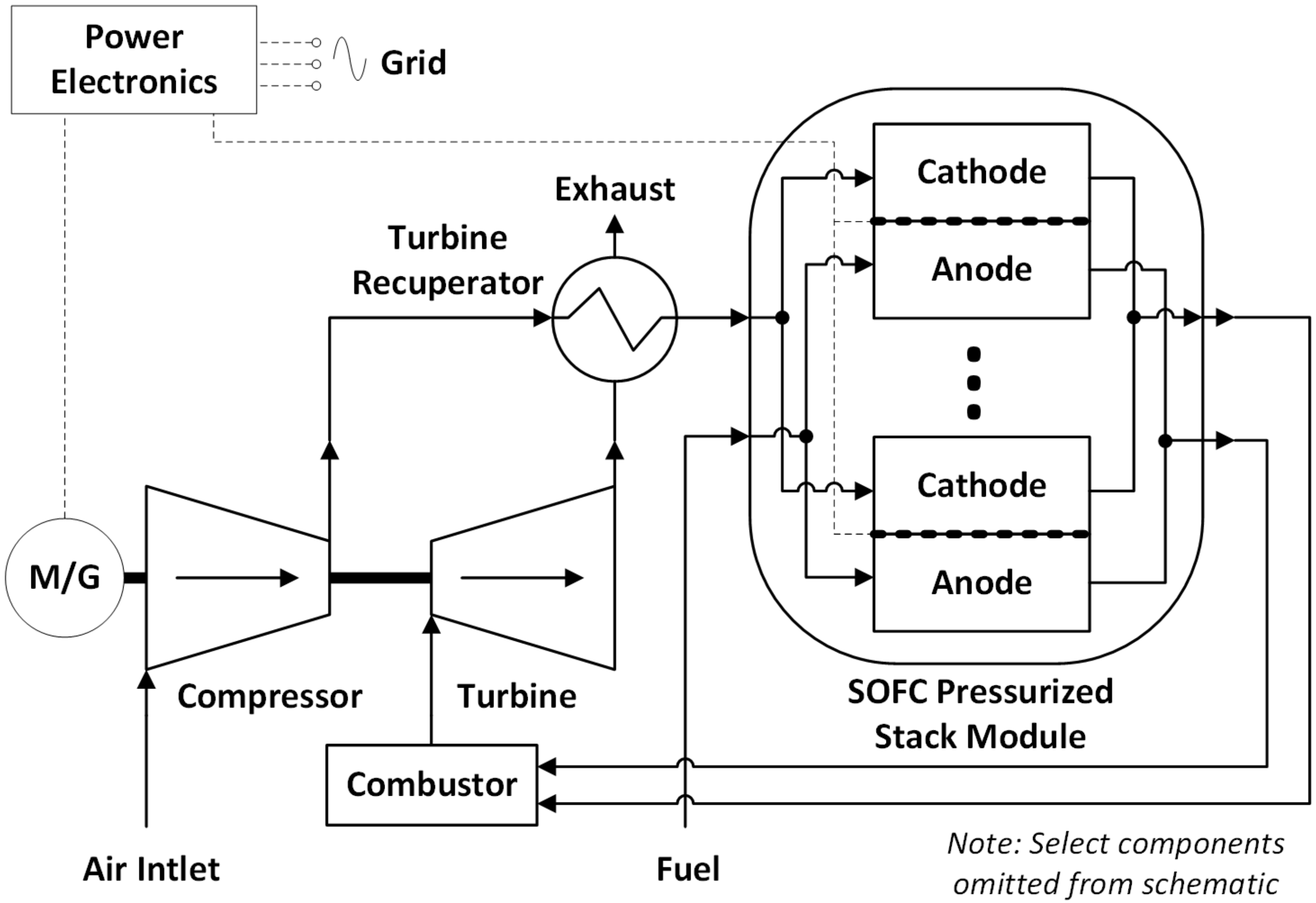
- Real+ideal gas properties (REFPROP)
- Individual species tracking: N_2, O_2, H_2O, CO, CO_2, H_2, CH_4, C_2H_6, C_3H_8
- Equilibrium chemistry (MSR/WGS) and mixture modeling
- Predominantly physics-based
- SOFC and GT subsystems validated at steady-state
- *Faster than real-time



Key Findings from Dynamic System Analysis

- Higher SOFC temperatures improve system efficiency*
- Higher turbine inlet temperatures improve system efficiency*
- Flow from the GT helps reject heat generated in the SOFC

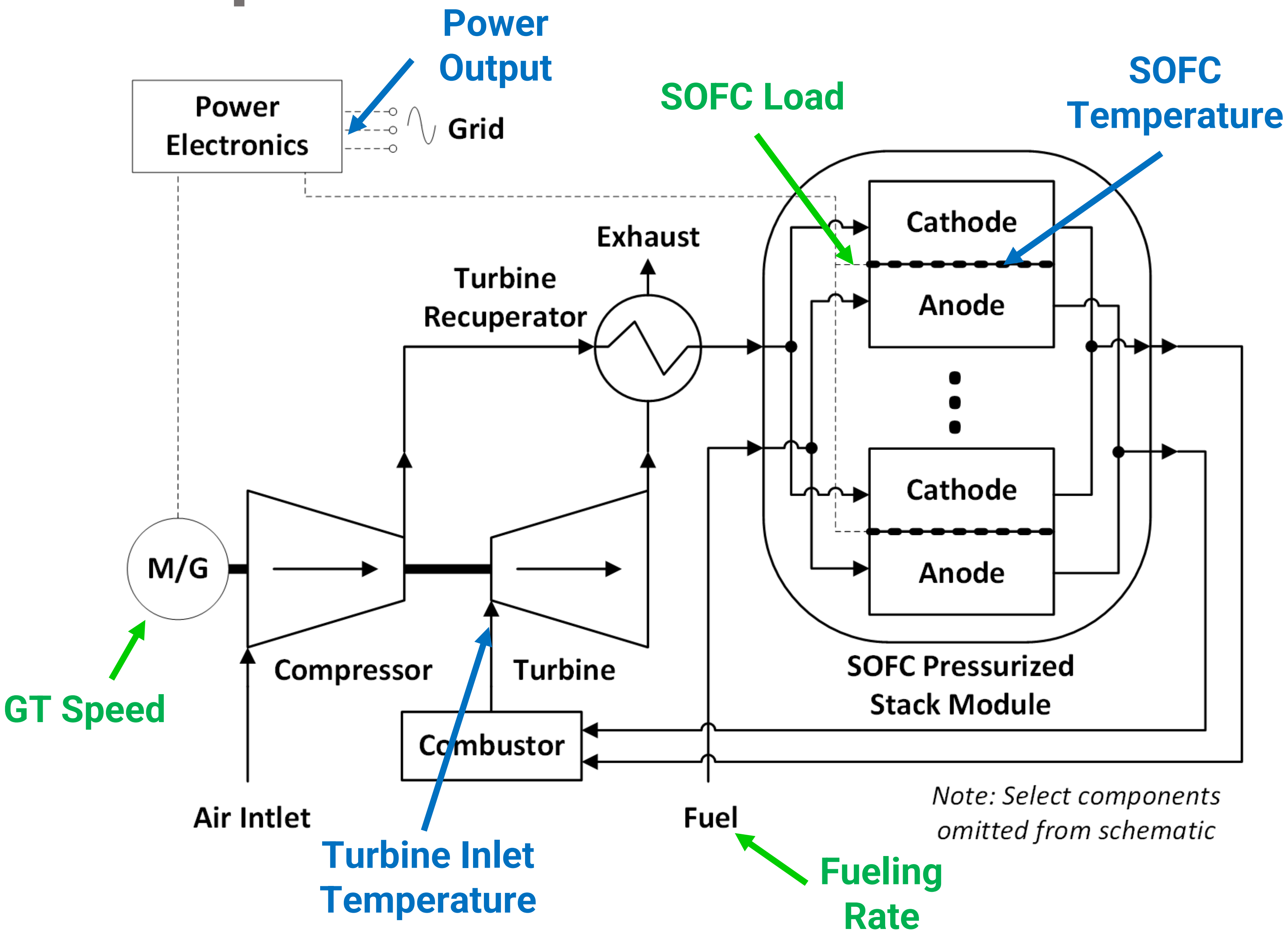
*Maximum temperature limited by material constraints



Note: Select components omitted from schematic

Principal Control Loops

- Adjust fueling rate to control power output
- Adjust SOFC load to control maximum stack temperature
- Adjust GT speed to control turbine inlet temperature

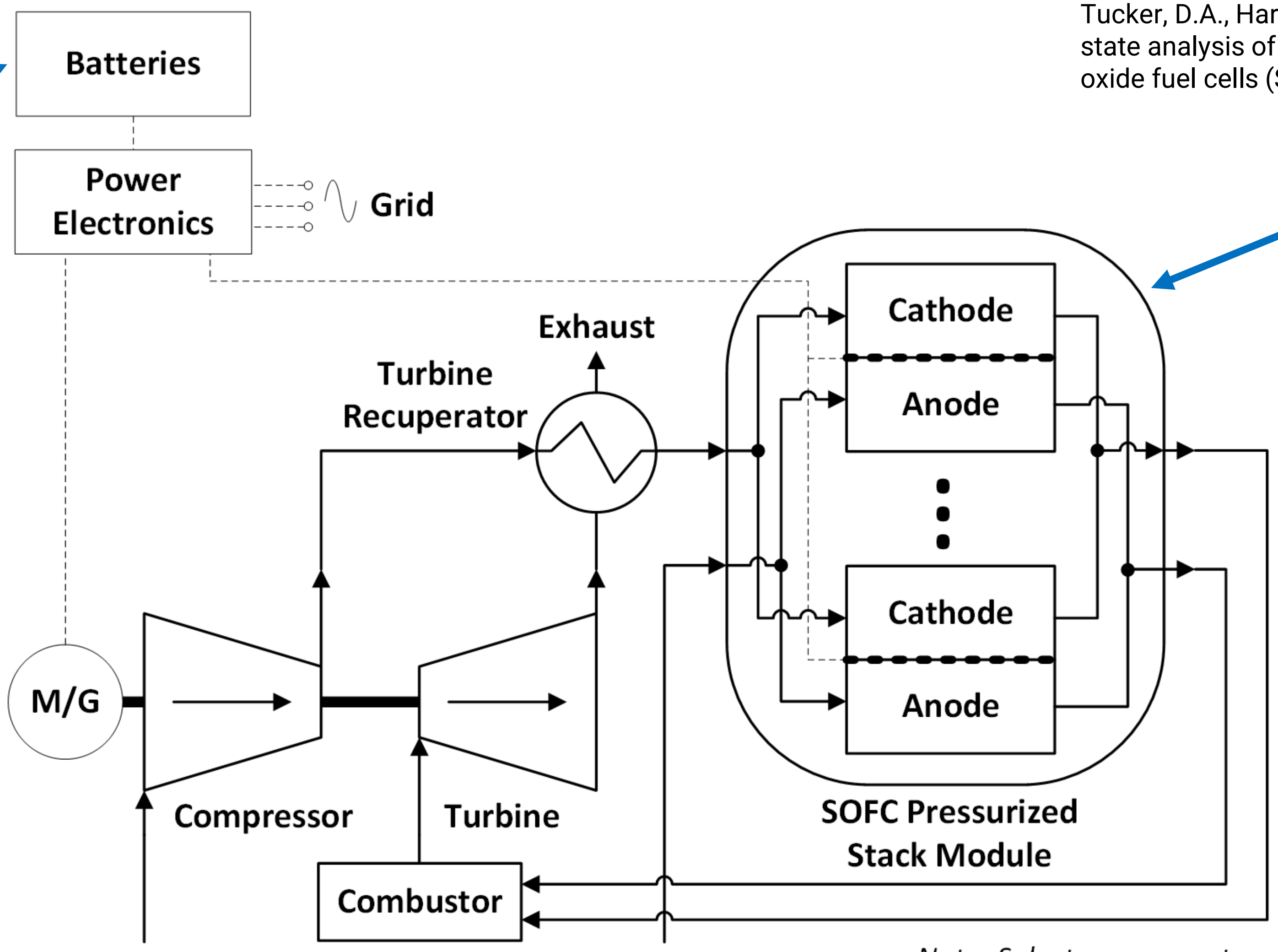


Energy Storage Concepts

Tucker, D.A., Harun, N.F. and Molo, F.L., 2016. Steady state analysis of direct thermal energy storage in solid oxide fuel cells (SOFC) (No. NETL-PUB-20794). NETL.

Electrical Energy Storage

Thermal Energy Storage



Note: Select components omitted from schematic

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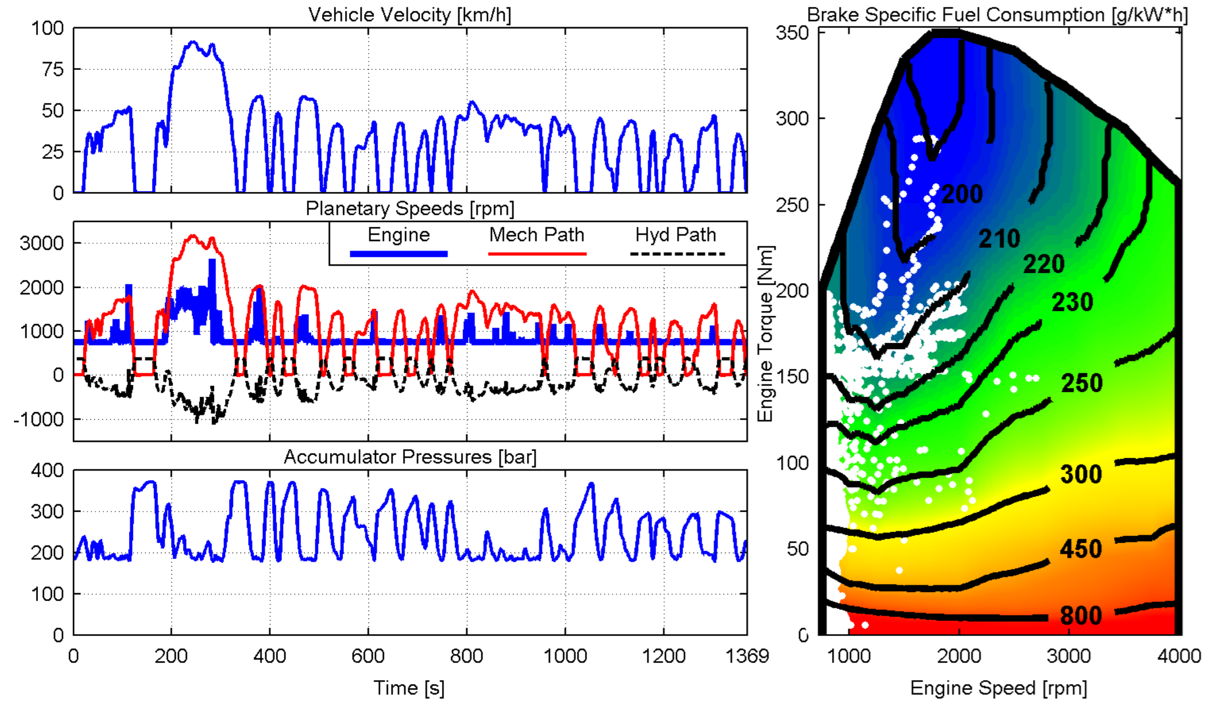
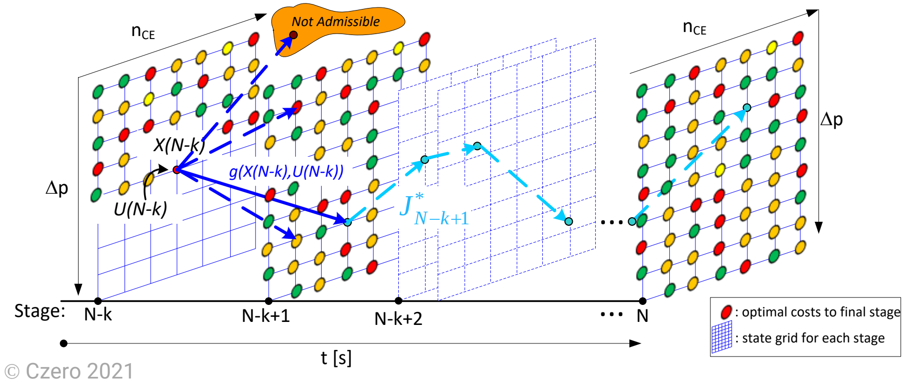
How is power best balanced between these varied sources

Globally Optimal Control via Dynamic Programming

- Guarantees global optimality (to the level of state/control discretization)
- Determine a system's maximum possible performance
- Discover effective, but perhaps counterintuitive, control schemes
- Provide a baseline for comparing implementable control strategies
- Non-implementable (*a-priori* knowledge)



Globally Optimal Control Trajectories generated by Dynamic Programming



Thanks for Your Attention

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