Gradient-Based Optimization of Power and Thermal Management Systems

Tool Design and Application to MDO Problems

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Gradient-Based PTMS Optimization

• Motivation

• Tool Development
  • Existing tools
  • Initial tool design
  • Revised approach

• Studies
  • Vehicle/sub-system co-design
  • Feedback controller sizing
  • Coupled vehicle/sub-system/controller sizing

• Concluding Remarks
  • Lessons learned
  • Contributions
Motivation
We seek to increase confidence in performance during design.
PTMS modeling includes high complexity subsystems.

Turboprop model (Abolmoali et al., 2020)
PTMS optimization highlights thermally limited vehicles.

Falck, et al., 2017

\[ h \text{ (km)} \]

Jasa, et al., 2018

increasing \( Q_{env} \)

Findings support previous conclusions by Bergholz and Hitch (1992).
PTMS models used in optimization are comparatively simple.

Models also do not include feedback controllers typically found in realistic systems.

Jasa et al., 2018

Brelje et al., 2019 [OpenConcept]
Tool Development
Existing PTMS Tools

• Academia
  • Graph-based models
    • Complex systems
    • Have not provided gradients
  • Optimization-based tools
    • Python/OpenMDAO
    • Simple systems
    • Provide gradients for optimization

• Industry
  • Simulink/Matlab-based
  • Allow creation of complex subsystems
  • Do not provide gradients
Graph models are based on energy conservation laws.

**Vertices:** energy stored within the system

**Edges:** energy moving within the system

**Sources:** energy entering the system

**Sinks:** energy leaving the system

Graph-based components

Battery

Inverter

Heat Exchanger
Initial tool implementation

Fluid Tank

OpenMDAO representation
Initial tool implementation

Fluid Tank

OpenMDAO representation
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Initial tool implementation

Fluid Tank

OpenMDAO representation
Initial tool implementation

Multiple PTMS components assembled together into a system
Revised Approach

System definition (Matlab)

OpenMDAO representation

Code Generation
functions, partials, metadata
Studies
Notional Vehicle
Series Hybrid System

- Battery
- Bus
- Inverter
- Motor
- Propeller
- Tank
- Rectifier
- Generator
- Cold Plate
- Heat Exchanger
- Shaft

Flow rates:
- $\dot{m}_1$
- $\dot{m}_2$
- $\dot{m}_{HX}$
Tightly Coupled ODE
Feedback Controller Sizing

Vehicle/Subsystem/Controller Co-Design

Concluding Remarks
Small components may be easier, but come at a substantial performance cost.
Contributions to Vehicle Design

![Graph showing contributions to vehicle design](image)

- Use of PTMS tool in conceptual design
- Higher-fidelity analyses, coupling

Confidence in Design Performance vs. Design Progress/Time

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Questions