Logic-Based Control of a Hybrid Thermal Management System

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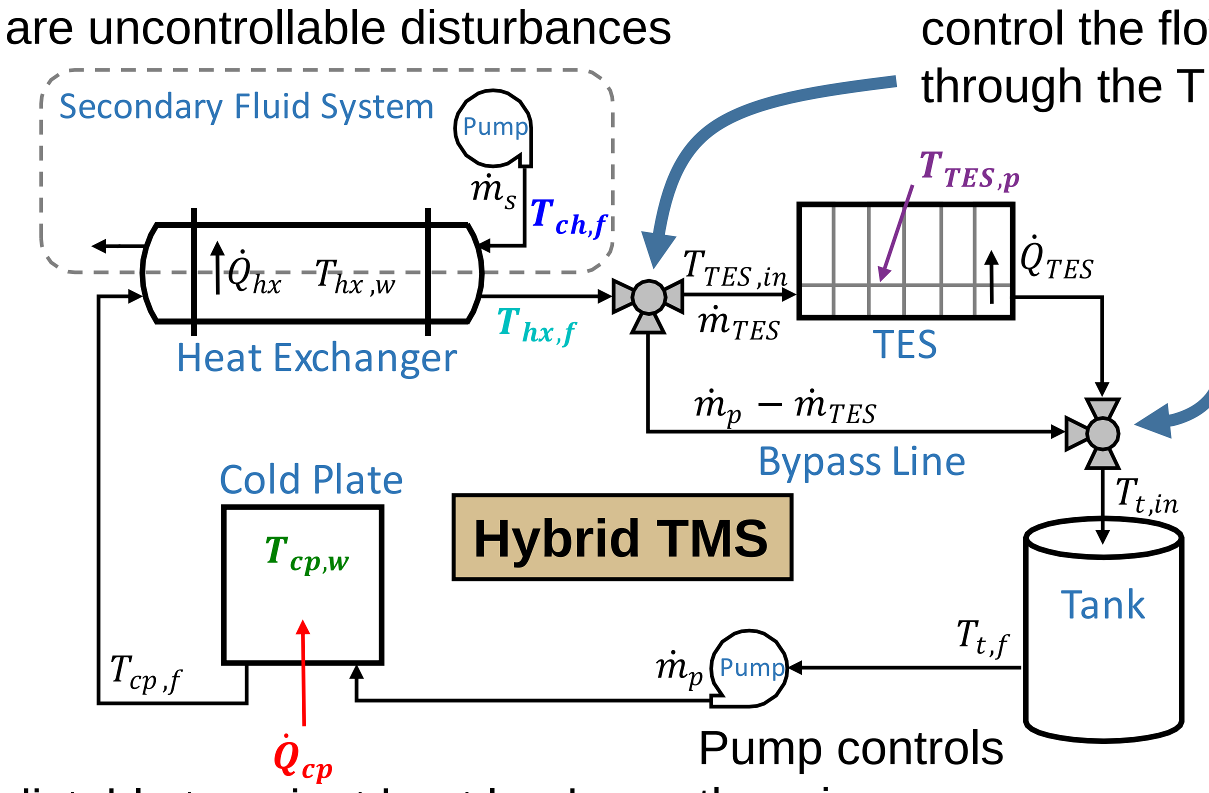
Abstract

- **Hybrid thermal management systems** (TMSs) are those that provide robustness against highly transient heat loads produced by increasingly electrified air vehicles by integrating phase-change **thermal energy storage** (TES) devices into the thermal-fluid loop
- TES is designed to provide additional heat rejection capacity only when needed, so its operation must be **actively controlled**
- **Logic-based control strategies** are easy to implement and not computationally expensive

Approach and Methodology

Secondary fluid flow rate ($\dot{m}_s$) and temperature ($T_{ch,f}$) are uncontrollable disturbances

Variable two-way valves control the flow rate through the TES, $\dot{m}_{TES}$

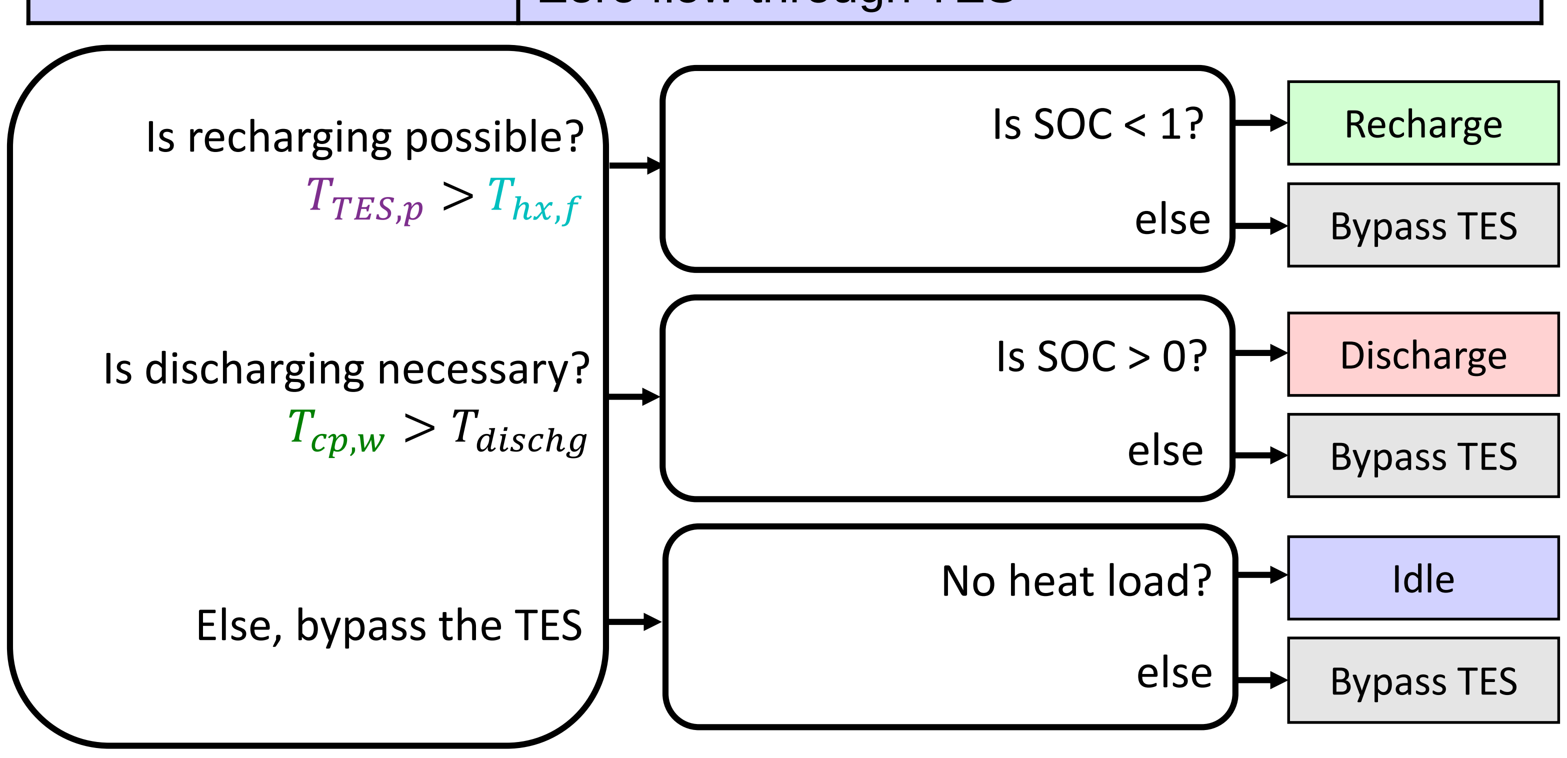


Unpredictable transient heat loads are applied through the cold plate

Pump controls the primary flow rate, $\dot{m}_p$

Controller Logic

Operation Mode	Control Action
Recharge (remove heat from TES)	Maximum primary flow rate Maximum TES flow rate
Discharge (use TES as heat sink)	Maximum primary flow rate TES flow rate proportional to cold plate temperature
Bypass TES	Maximum primary flow rate Zero flow through TES
Idle (Low flow rate)	Reduce primary flow rate to 10% of maximum Zero flow through TES



SOC: State of charge is a function of the remaining storage capacity.

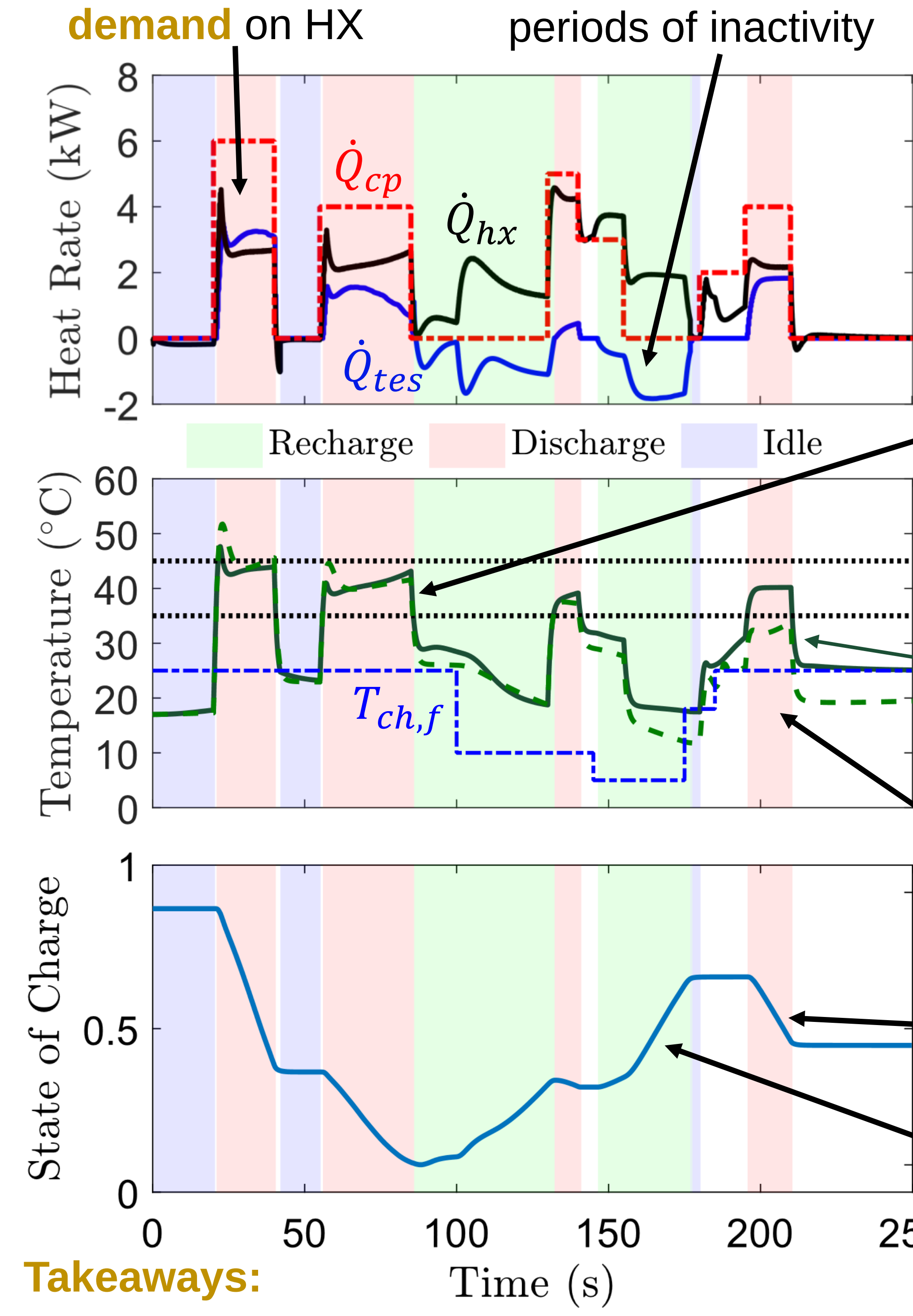
- SOC = 1 means no heat is stored (PCM is solid)
- SOC = 0 means no more heat can be stored (PCM is liquid)

Simulated Case Study

The following case study **simulates** the proposed heuristic controller for the hybrid TMS and compares it to a **benchmark conventional TMS** which does not use thermal storage.

Controller Objective: Keep the cold plate surface ($T_{cp,w}$) below the maximum allowable temperature (45ºC).

Benchmark TMS: A conventional TMS (no thermal energy storage) with same cold plate as hybrid TMS but heat exchanger with 4x length and tank with 4x volume of fluid to keep cold plate from overheating



Takeaways:

- The TES reduces demand on the heat exchanger by storing large transient heat loads to be rejected during periods of inactivity
- Including TES allows the primary heat rejection components to be downsized, potentially reducing system mass and volume.

Summary & Future Work

Key Contributions

- Integrating TES into a TMS along with an appropriate controller allows the primary heat rejection components to be downsized, **saving both mass and volume**
- Heuristic logic-based control strategies perform well even when the upcoming heat loads are not known in advance

Future Work

- Implement and validate the controller on an experimental testbed
- Benchmark the proposed heuristic strategy against an optimal one

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