P/O/E/T/S

CENTER FOR POWER OPTIMIZATION OF ELECTRO-THERMAL SYSTEMS

Battery Pack Power-Thermal Co-Management System Design Optimization for Enhanced Reliability and Safety Performances

I1.021.22

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Outline

- Impact and Exec Summary
- Single Cell Experiment and Simulation
- 8 Cells Module Experiment and Simulation
- Battery Layout and Control Optimization
- Plan for Next 3 Months

Battery Management System Co-design

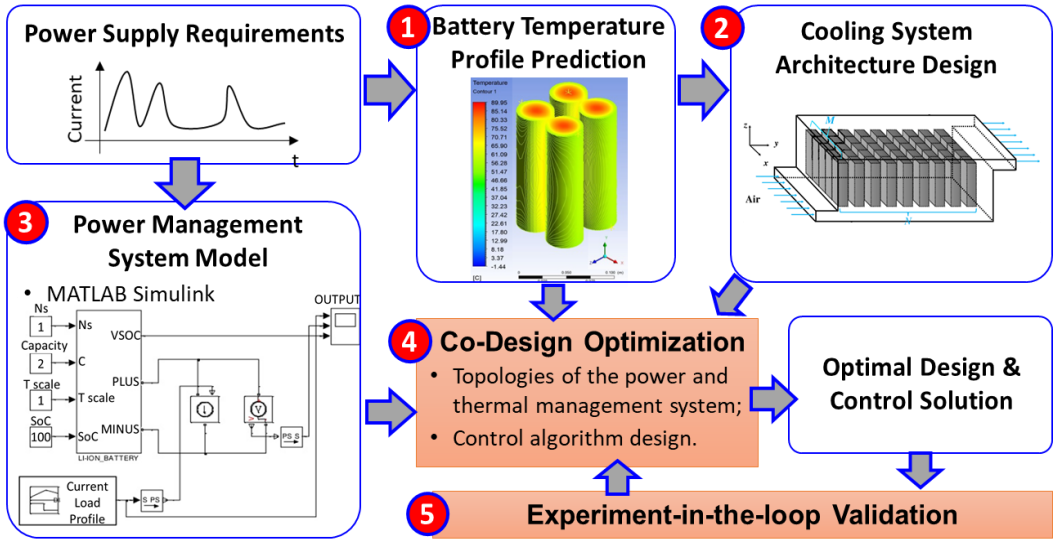
Why | What | How

More Power

Battery Applications:

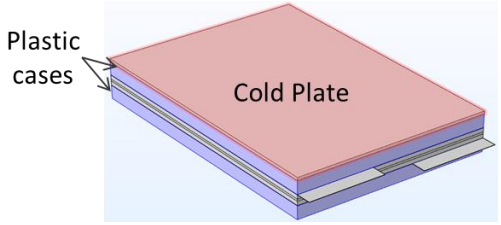
- Cell phones
- Tablets
- Laptops
- Electric vehicles
- Electric flights
- Grid-scale energy storage systems

Bigger Battery Pack



Battery Management System:

- Includes *power* and *thermal* managements
- Often designed *separately* or *sequentially*
- Usually ignored their *coupling effects*
- Leaded to *low energy efficiency* and *short battery life*



Control Co-Design

Why | What | How

Plant design:
- Batteries layout

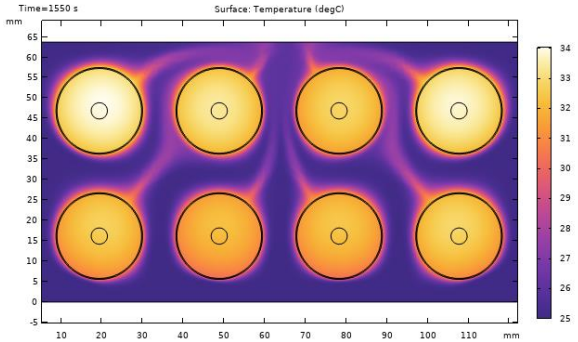
Control design:
- PI control parameters (K_P, K_I)

Objective function:
- $\int V \Delta p \, dt$
- Energy consumption by pump
- V: coolant flow rate
- Δp: pressure drop

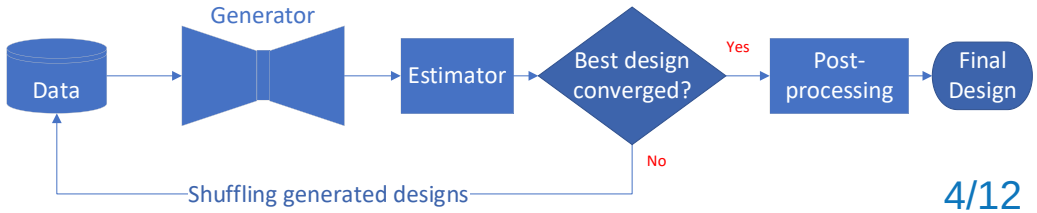
Constraint:
- Battery temperature lower than 35 °C

Experiment

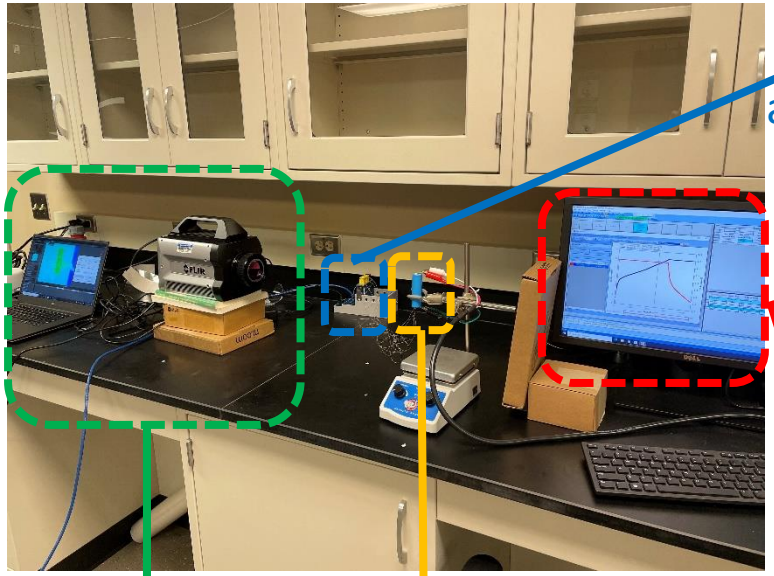
Simulation

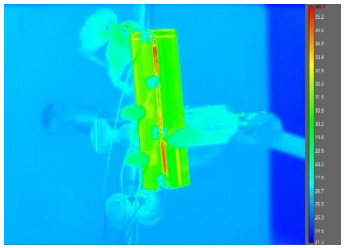


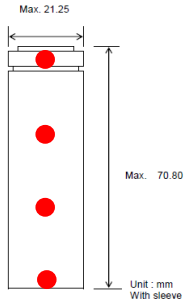
Generative adversarial network

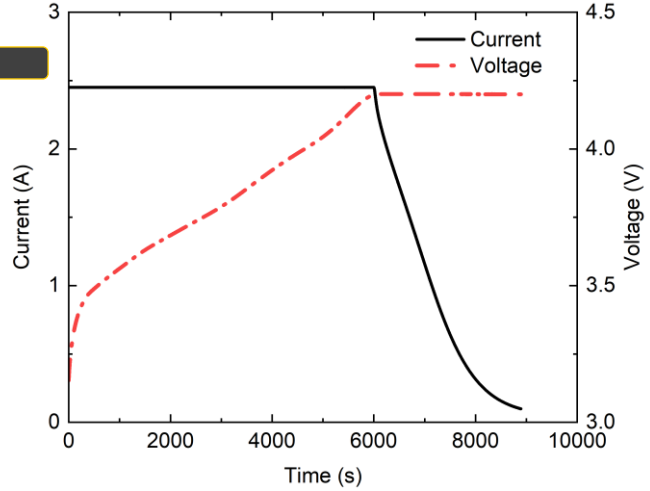


Single Cell in Air Experiment

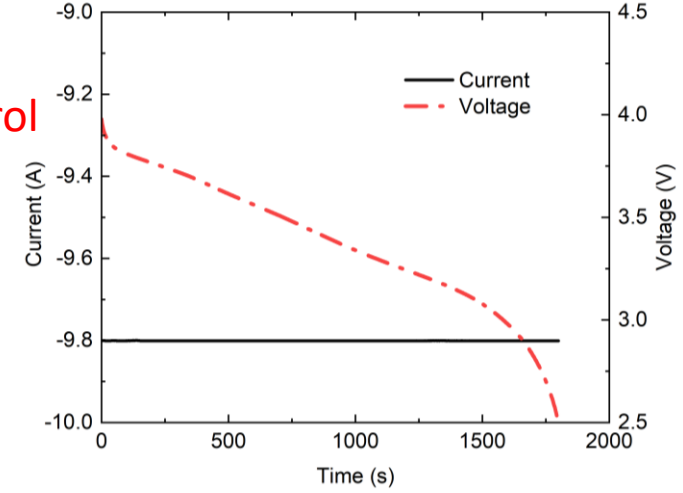






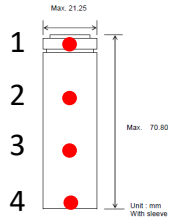


CCCV Charging (1C)



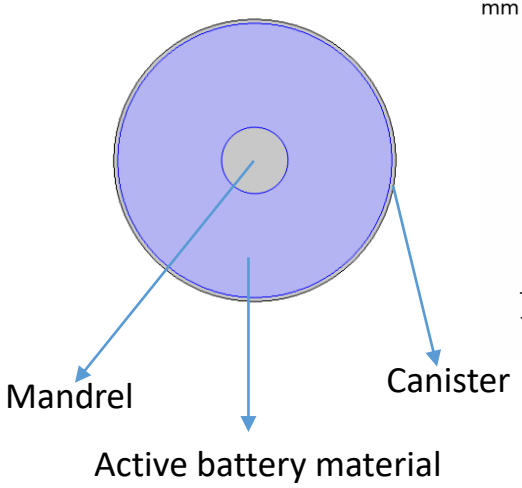
CC Discharging (2C)

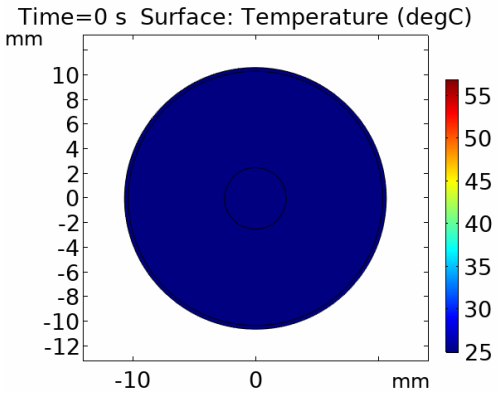
Single Cell in Air Simulation

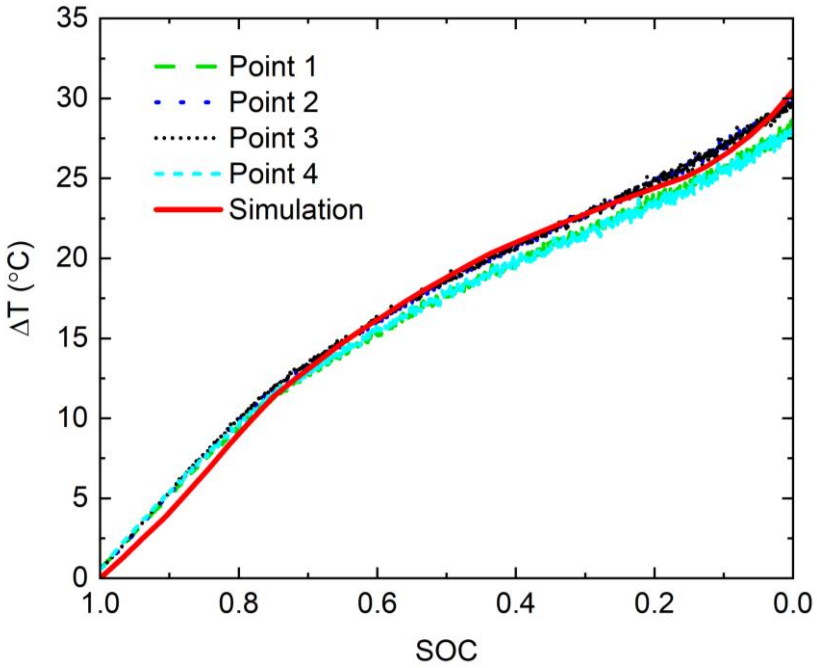


Why | What | How

Simplified battery structure:

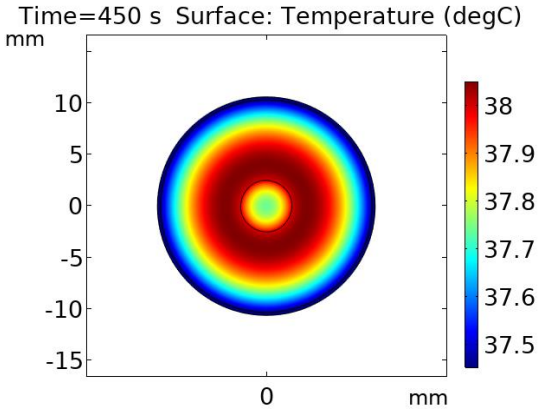






Temperature at 2C discharging

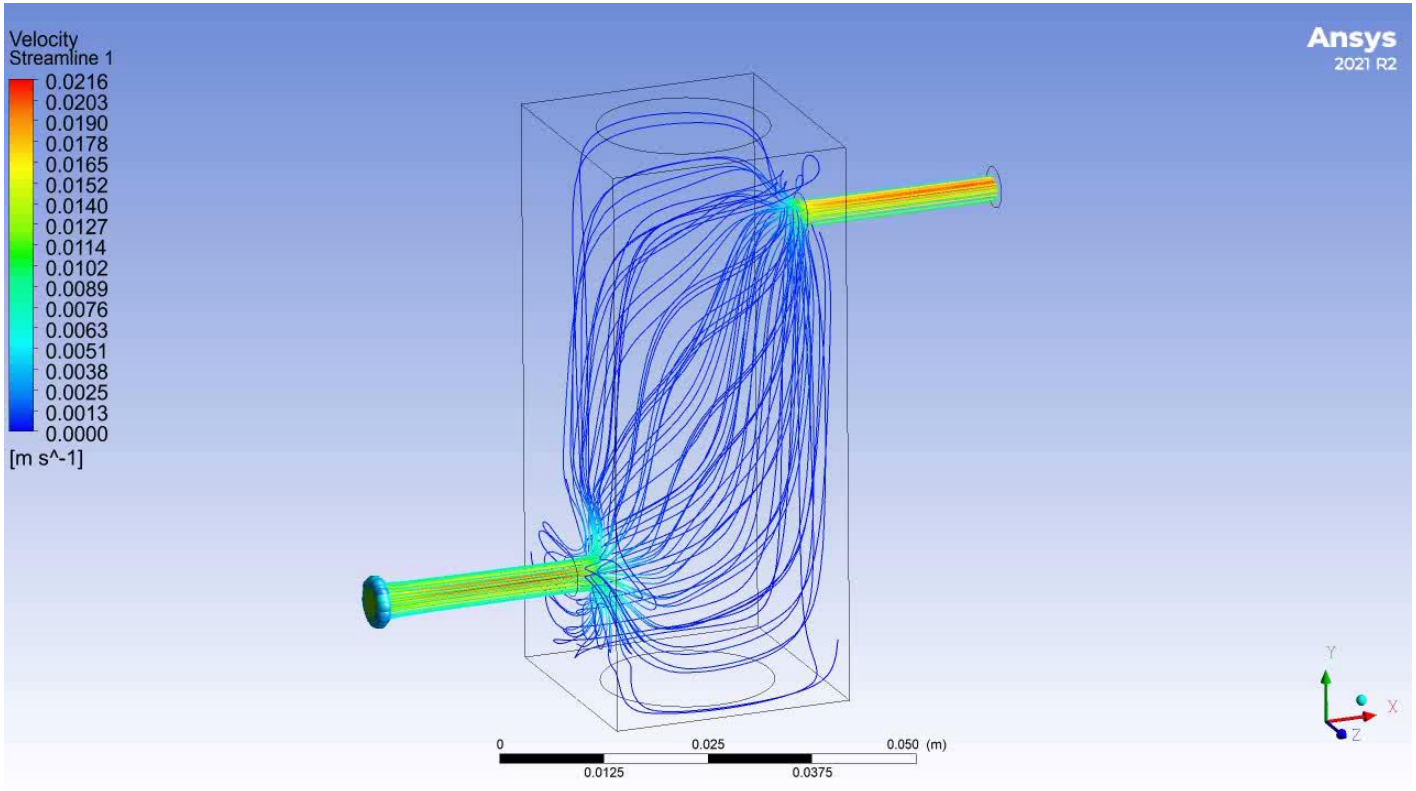
- 3D -> 2D
- Accelerate simulation

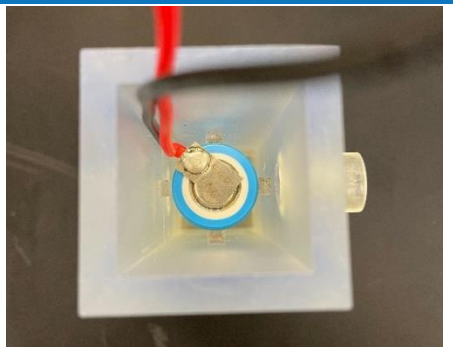


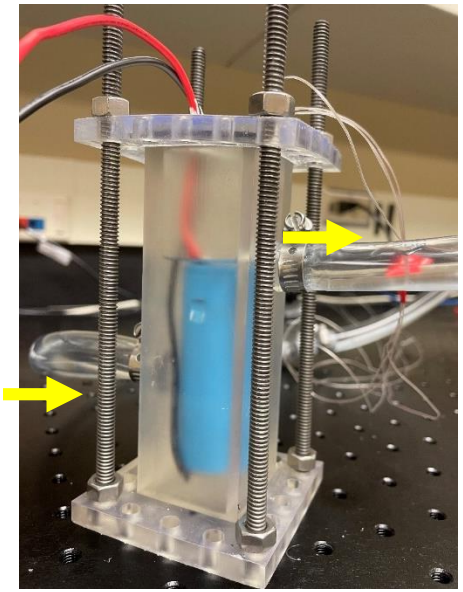
- Point 1-4 are from experiment
- Point 1 and 4 have relatively low temperature (no active material)
- Simulation has high fidelity

Single Cell in Coolant Experiment and Simulation

Why | What | How







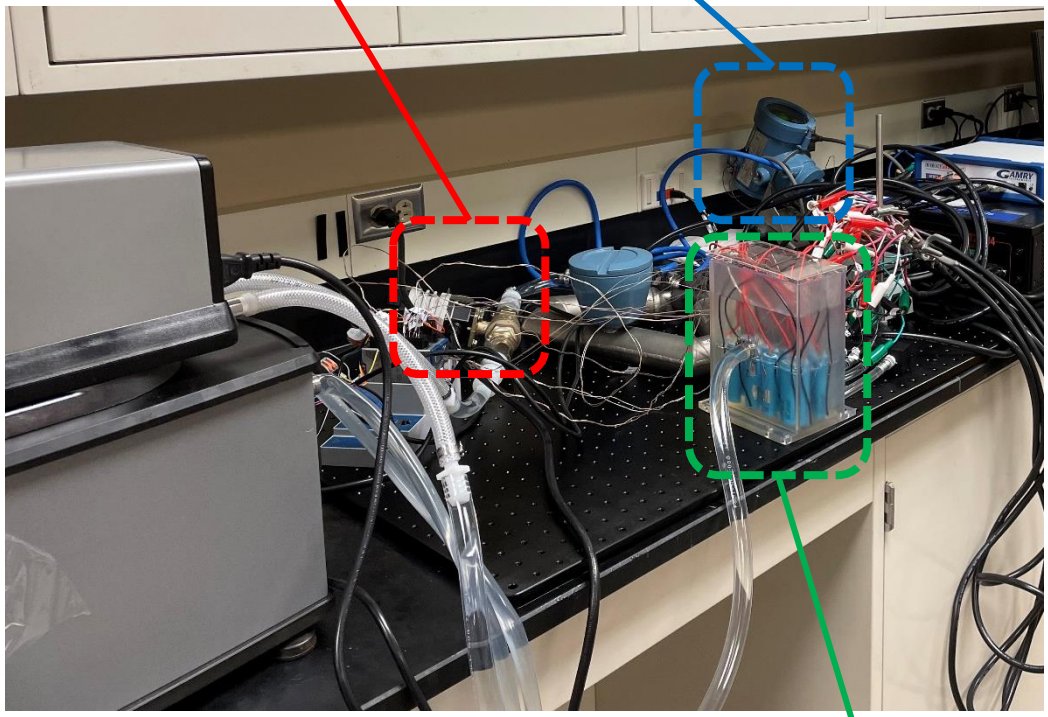
One cell chamber

Battery Module Experiment

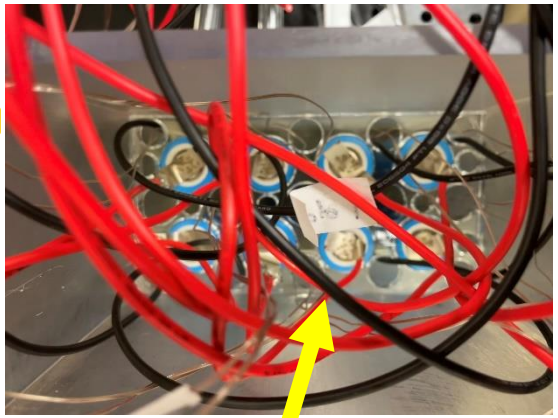
Why | What | How

Control valve

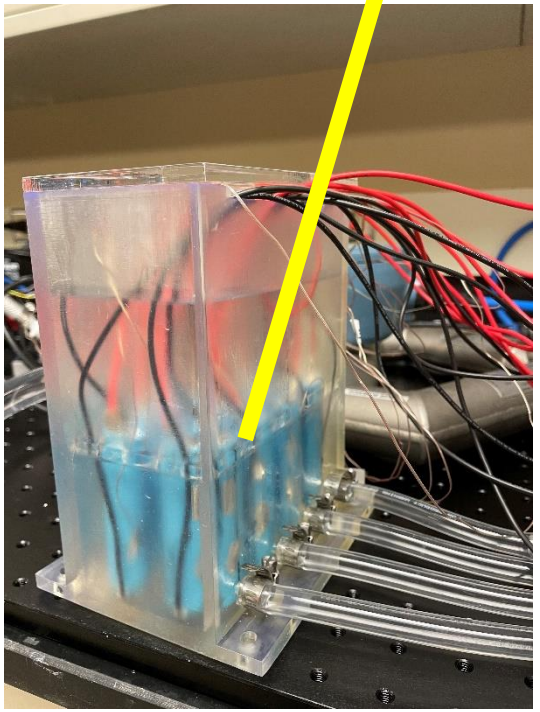
Flow meter



8 cell module chamber



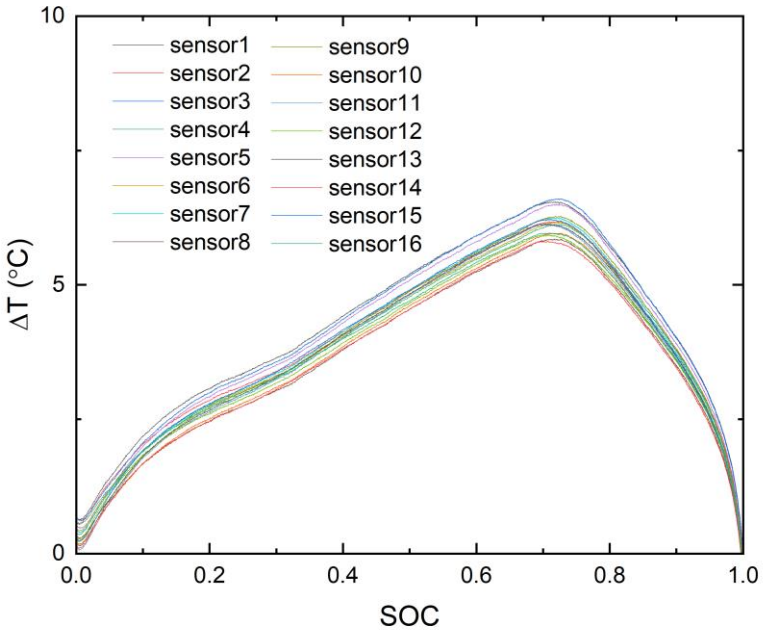
Constraint plate



3D printing

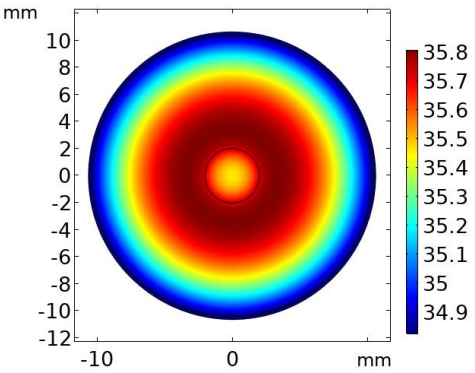
Battery Module Experiment

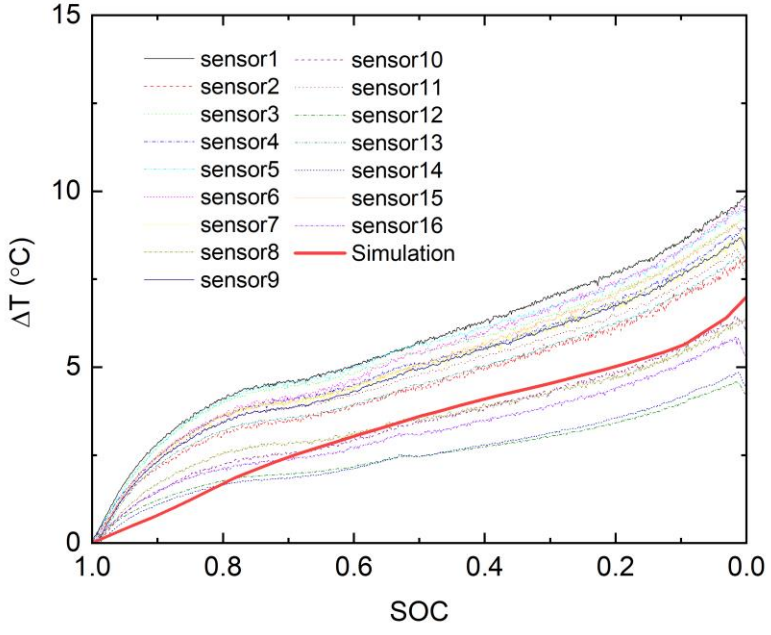
Why | What | How



CCCV Charging (1C)

- Immerse in coolant
- No flow
- No active cooling needed





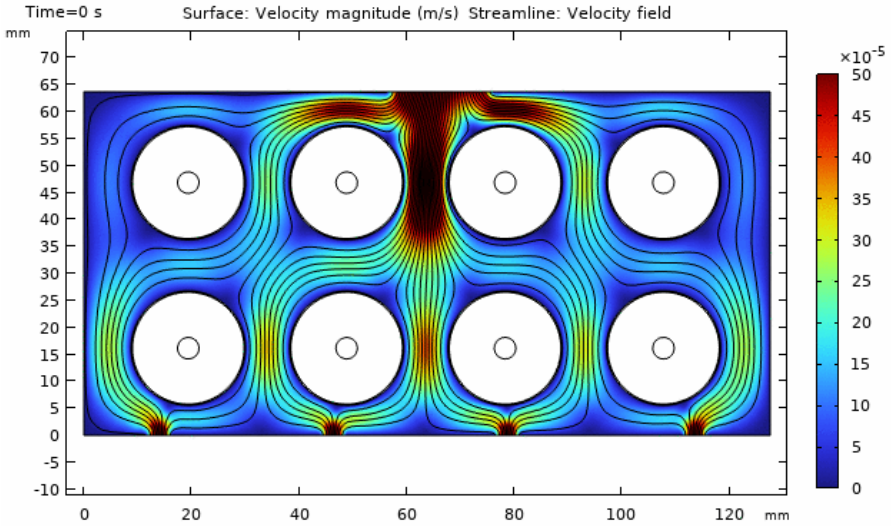
CC Discharging (2C)

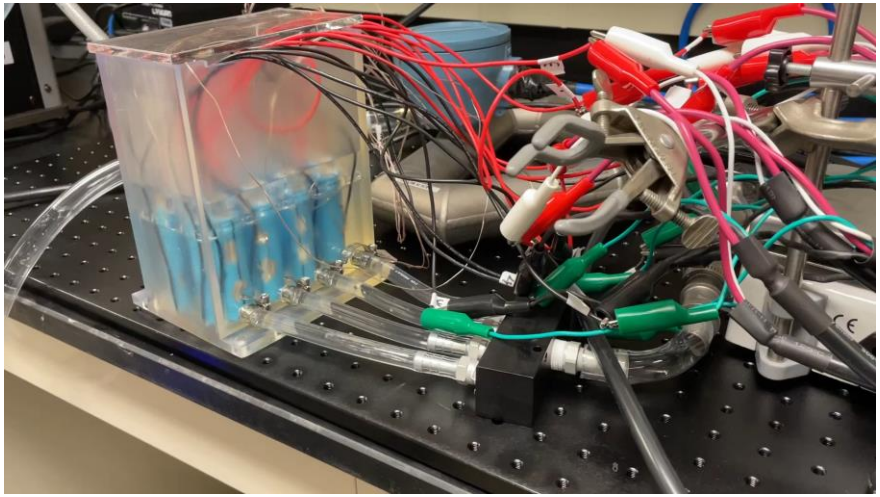
- Immerse in coolant
- Flow rate = 0.01965569 kg/s
- Active cooling needed
- Simulation has high fidelity

Battery Module PI Control Simulation

$$Flow\ rate = Bias + K_P(T_{limit} - T_{max}) + K_I \int_0^t (T_{limit} - T_{max,\tau})d\tau$$

Why | What | How

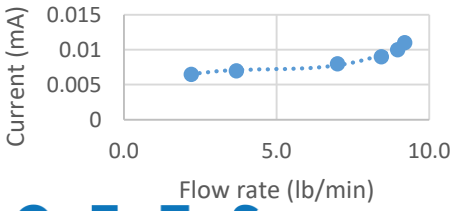




Simulate flow rate PI control

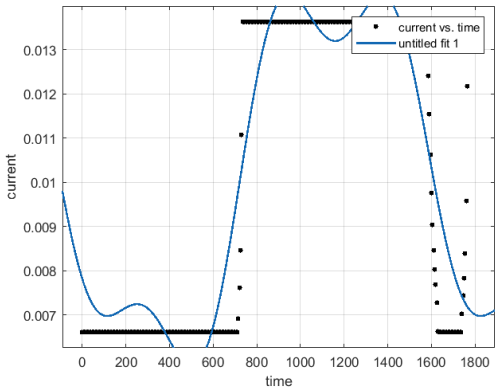
K_P, K_I

Convert flow rate to valve current

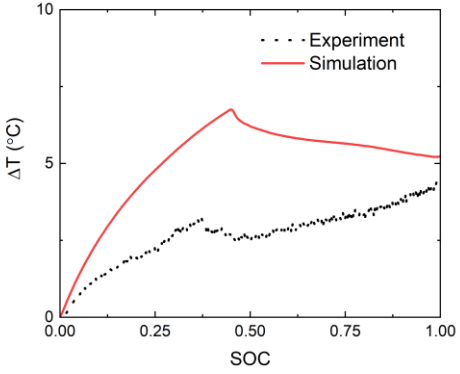


Fourier curve fitting

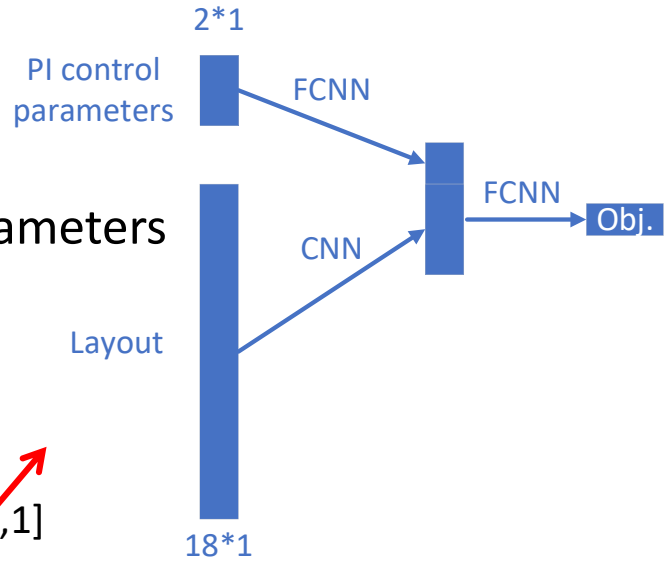
Valve control flow rate | Experiment



Temperature verification

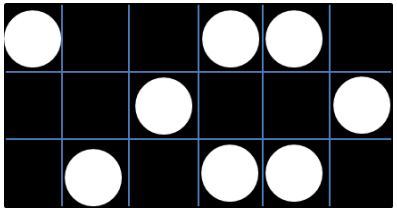


Battery Layout and Control Optimization

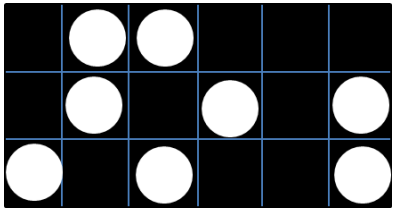


Why | What | How

Step 1: Random generate 1,000 layout and control parameters



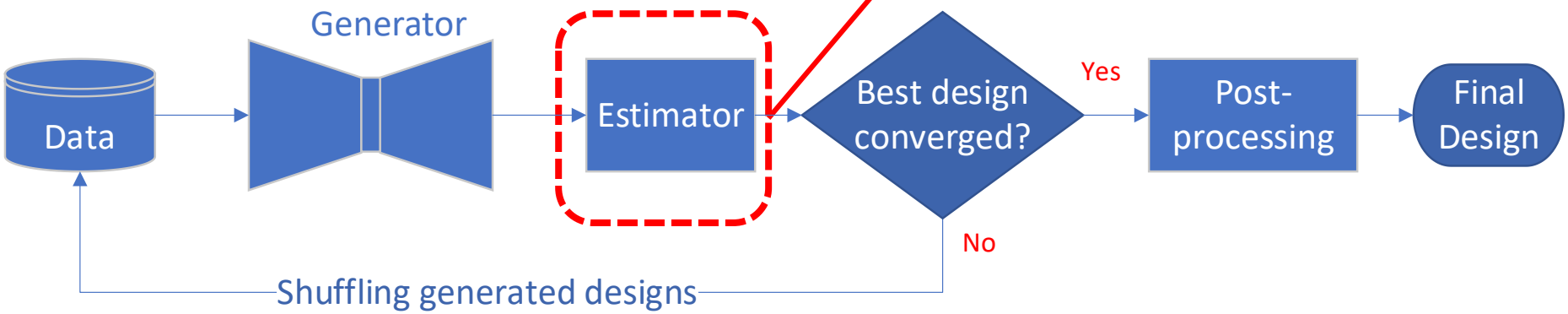
[1,0,0,1,1,0,0,0,1,0,0,1,0,1,0,1,1,0]



[0,1,1,0,0,0,0,1,0,1,0,1,1,0,1,0,0,1]

K_P, K_I

Step 2: Use generative adversarial network to optimize layout



Plans for remaining 3 months

Battery Layout and Control Optimization

Why | What | How

- Finish the simulation of 1,000 combinations of layouts and PI parameters
- Random select 10 combinations of layouts and PI parameters to verify by experiment
- Finalize generative adversarial network
- Train generative adversarial network and obtain the optimized layouts and PI parameters
- Try to adapt the method to different coolant
- Try to adapt the method to different cooling methods

4 Cells Simulation