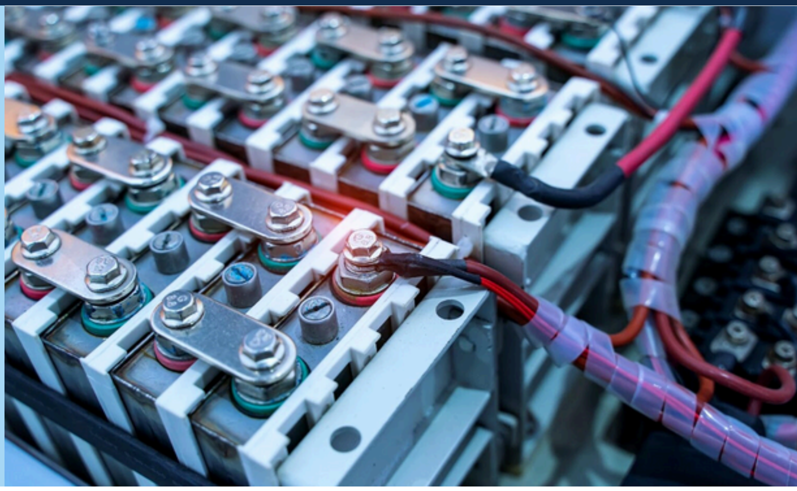
HeatSync Case Study

Thermal Management for an EV Battery Pack

OVERVIEW

HeatSync designed and optimized a thermal management solution for a 90 kWh Li-ion EV battery pack to maintain optimal temperature, prevent thermal runaway, and ensure long-term reliability. Utilizing advanced simulations, testing, and real-time Digital Twin models, the solution enhances battery performance, safety, efficiency, and lifespan under diverse conditions.



CLIENT REQUIREMENTS

The thermal management system maintained battery cell temperatures to prevent aging, lithium plating, and thermal abuse. Designed for efficient cooling and heating under various conditions, it also met space, manufacturability, serviceability, weight, and cost constraints for seamless vehicle integration.

SOLUTION DEVELOPMENT

1. BATTERY CHARACTERIZATION

A test sequence was conducted to characterize battery behavior under normal use conditions:

- **Preconditioning:** Removed passivation and stabilized capacity.
- **Relaxation Test:** Determined thermodynamic stability.
- **Capacity Test:** Assessed performance variations under different temperatures and load currents.
- **OCV Measurement:** Measured open-circuit voltage for state-of-charge (SOC) analysis.
- **Hybrid Pulse Power Characterization** (HPPC) & **Electrochemical Impedance Spectroscopy** (EIS): Identified the battery's electrical and thermal response to transient loads.

2. THERMAL LOAD ESTIMATION

Using an Equivalent Circuit Model (ECM), the real-time heat dissipation rate was estimated under various charge/discharge conditions, SOC levels, and temperatures to develop an efficient cooling strategy tailored to the battery pack's operating environment.

3. THERMAL SYSTEM DESIGN

The cooling system, designed with cold plates, regulated battery cell temperatures while meeting hydraulic, thermal, and manufacturing constraints. **Coolant flow distribution** was optimized, while **temperature gradients** across cells, modules, and the pack were controlled for consistent performance. **Manufacturing considerations** guided the design of cold plates, material compatibility, and fittings for efficient production and assembly.

Using 3D transient CFD simulations, HeatSync optimized the cold plate and manifold design, solving for continuity, momentum, and energy equations to ensure accurate temperature distribution and cooling efficiency. The model was validated against test data and refined for optimal performance.

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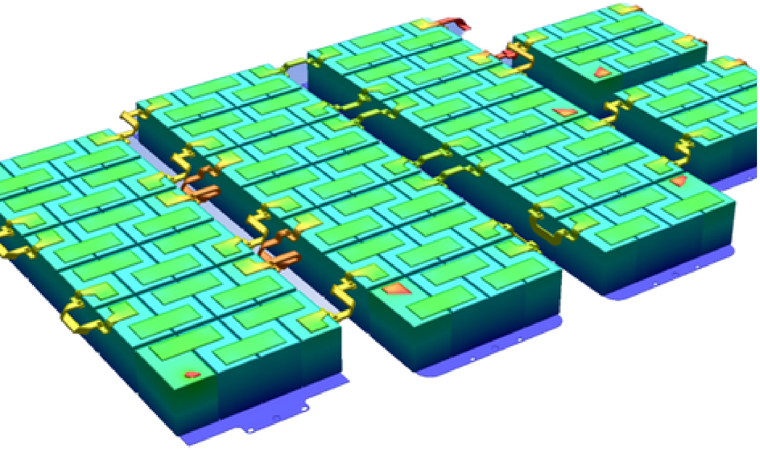

4. TESTING

A full-scale prototype of the battery pack was built to validate the thermal management system. Tests included:

- **Performance Verification:** Measured temperature uniformity, cooling efficiency, and pressure drop.
- **Structural Integrity Tests:** Burst pressure, coolant leak detection, and thermal shock resistance.

5. REAL-TIME MONITORING

To enhance real-time temperature monitoring, HeatSync integrated virtual sensors into the battery management system (BMS). These sensors:

- Estimated **temperature distribution** across the pack without requiring extensive physical sensors.
- Enabled **predictive thermal management**, reducing reliance on static lookup tables.
- Provided **remote monitoring** capabilities for troubleshooting and maintenance.

6. OPERATING SETTINGS

The battery pack's thermal management was optimized using an AI-driven Digital Twin/ML system integrated into the Thermal Control Unit (TCU). This system optimized cooling in real time, minimizing energy use while maintaining passenger comfort. Using genetic algorithm-based optimization, the TCU dynamically adjusted coolant flow, operating temperature, and power consumption, balancing battery performance, HVAC efficiency, and thermal stress reduction to extend battery life.

RESULTS AND CONCLUSION

HeatSync's thermal modeling, testing, and real-time digital twin optimization successfully managed a 90 kWh EV battery pack, ensuring temperature regulation, safety, and efficiency. The system minimized lithium plating, aging, and thermal runaway risks while optimizing energy efficiency and reducing cooling power consumption.

By integrating cold plate cooling, AI-driven optimization, and virtual sensors, HeatSync enabled real-time monitoring, predictive maintenance, and troubleshooting, enhancing reliability. The system passed rigorous validation tests, ensuring structural durability and compliance with safety standards.

Contact HeatSync today to learn more about our cutting-edge design, simulation, testing, and training services for reliable thermal management solutions.

HeatSync: Consortium of Thermal Management

+1 (408) 650 2999

info@heat-sync.com

www.heat-sync.com

Cupertino, CA 95014