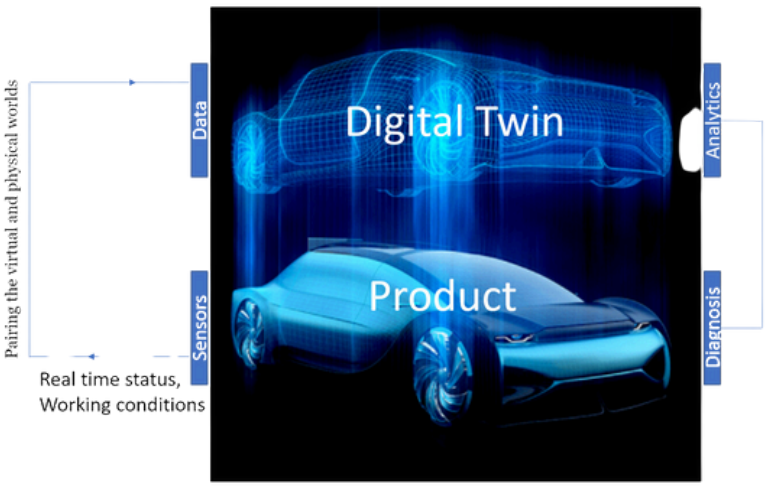
HeatSync Case Study

Digital Twin for Predictive Thermal Management of EV Battery Packs

OVERVIEW

HeatSync developed a Digital Twin model for a 90 kWh lithium-ion (Li-ion) battery pack to optimize thermal management, performance, and safety in electric vehicles (EVs). This advanced model enabled real-time monitoring, predictive maintenance, and system-level optimization, allowing engineers to simulate and refine battery behavior under diverse operating conditions. By integrating live sensor data and reduced-order modeling (ROM), HeatSync's Digital Twin solution provided accurate temperature predictions while significantly reducing computational costs.



1. CLIENT REQUIREMENTS

- Accurately model battery pack temperature distribution under real-world conditions.
- Integrate live and virtual sensor data for predictive maintenance and remote diagnostics.
- Improve efficiency and reduce energy consumption while ensuring battery health.
- Reduce design iteration time by replacing time-intensive simulations with real-time predictive modeling.

2. DIGITAL TWIN MODEL DEVELOPMENT

The Digital Twin was developed using a semi-analytical model to predict real-time temperature distribution in the battery pack. A 2RC equivalent circuit model was used to calculate the real-time heat generation rate, integrating Hybrid Pulse Power Characterization (HPPC) tests for model calibration.

Key Features of the Digital Twin:

Live Sensor Integration: Incorporated real-time voltage, temperature, and SOC (State of Charge) data.
Equivalent Circuit Model (ECM): Used for dynamic thermal and electrical performance prediction.
Reduced Order Model (ROM): Enabled real-time computationally efficient simulations.

3. VALIDATION

To ensure accuracy, HeatSync validated the Digital Twin model against high-fidelity CFD simulations and experimental test data.
Simulation Approach:

- Transient 3D CFD simulations captured battery pack behavior under fast charging, cold starts, and high-discharge conditions.
- Equivalent Circuit Modeling (ECM) estimated heat generation as a function of SOC, temperature, and charge/discharge cycles.
- Model Calibration: The ECM parameters were refined using HPPC tests.

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The validation process showed strong correlation between the Digital Twin's predictions, CFD simulations and experimental test data, confirming its reliability for thermal monitoring and system optimization.

4. BENEFITS OF THE DIGITAL TWIN

The Digital Twin enabled predictive thermal management, monitoring heat generation, voltage, and SOC to anticipate thermal behavior. Acting as a virtual sensor, it detected issues early, eliminating extra physical sensors and enabling remote diagnostics.
Integrated into the cooling loop, it adjusted coolant flow and temperature for efficient cooling, balancing energy use, passenger comfort, and battery longevity.

Using degradation models, it predicted battery aging trends, preventing premature failures and ensuring long-term reliability.

5. CONCLUSION

HeatSync's Digital Twin technology optimized EV battery thermal management through real-time monitoring, predictive analysis, and cooling optimization. It ensured accurate thermal predictions, minimized thermal runaway, aging, and lithium plating risks, and improved cooling efficiency while reducing energy consumption. Predictive modeling extended battery life by minimizing thermal stress, enhancing durability.

By accelerating design validation and reducing iteration time, the Digital Twin streamlined development while ensuring safety, efficiency, and performance. Integrating sensor data, CFD validation, and AI-driven optimization, HeatSync's solution is a key tool for next-generation EV battery management.

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

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