1- Problem definition

The increasing adoption of electric vehicles (EVs) demands safe, efficient, and cost-effective battery management systems (BMSs). Lithium-ion batteries, while offering high energy density and long life, are highly sensitive to temperature variations. Operating outside their optimal thermal range accelerates degradation, shortens lifespan, and can trigger dangerous thermal runaway events.

In large-scale battery packs, accurate monitoring of both surface and core temperatures is essential to ensure safety and performance. However, direct measurement of core temperature is impractical in commercial applications due to invasive sensor placement, increased manufacturing complexity, and higher costs. Current solutions rely on installing numerous surface sensors, which increases wiring complexity, integration difficulty, and overall system cost.

The industry requires a method capable of estimating internal (core) and surface temperatures with minimal physical sensors while maintaining accuracy within ±1 °C — the typical safety margin for EV battery packs. This challenge involves developing computationally efficient, real-time estimation algorithms that can operate with reduced hardware, without compromising thermal safety or performance.

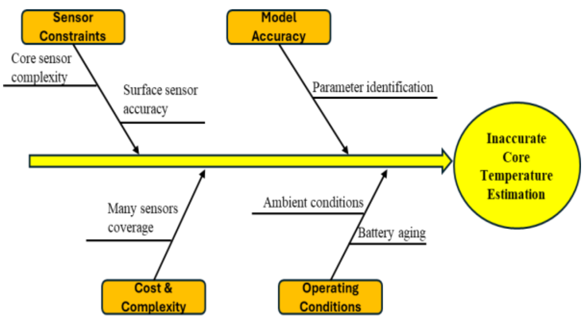
2- Current situation

In large EV battery packs, lithium-ion cells generate heat unevenly, with the core often up to 5 °C hotter than the surface under high load. Accurate monitoring of both core and surface temperatures is essential for safety, performance, and lifespan.

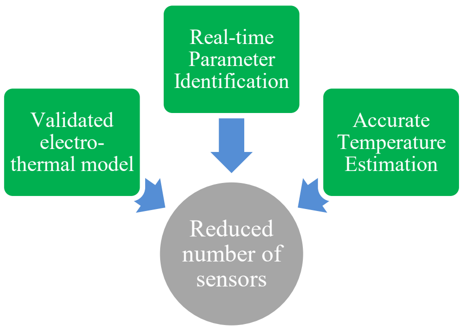
Currently, manufacturers rely on many surface sensors (e.g., 30–50 for a 100-cell pack) to monitor temperature distribution. This increases cost, wiring complexity, and weight while still failing to measure core temperature directly. Installing core sensors is invasive, costly, and impractical for mass production.

As a result, current systems struggle to balance accuracy, cost, and practicality, leaving room for methods that achieve reliable core temperature estimation with fewer sensors.

3- Analysis of causes



4- Target situation



Title: Core and surface temperature estimation of large-scale battery pack with reduced sensors
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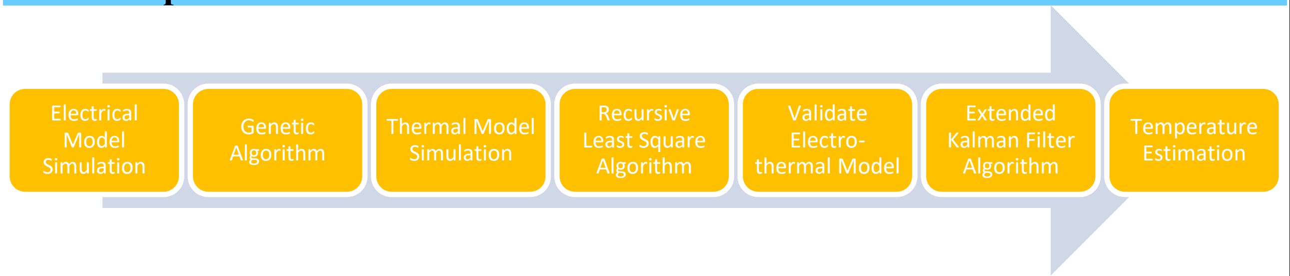
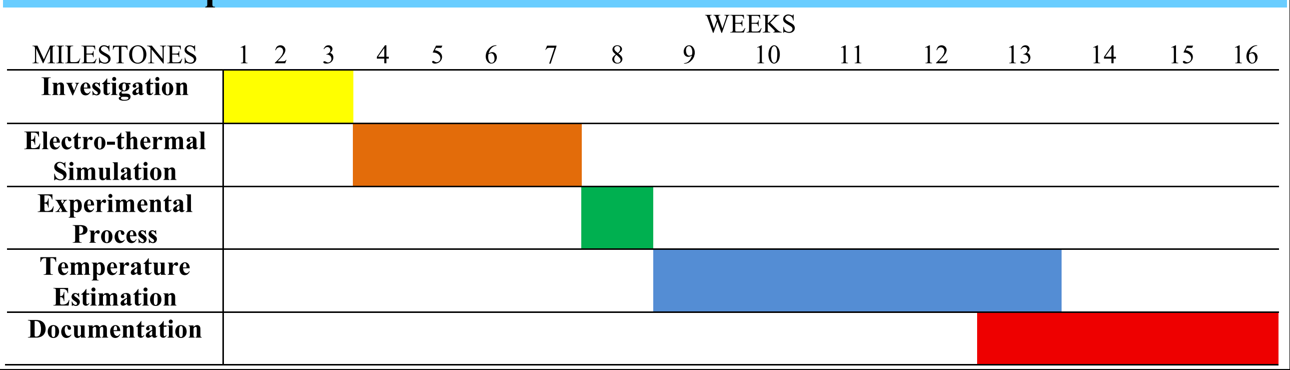
5- Action plan



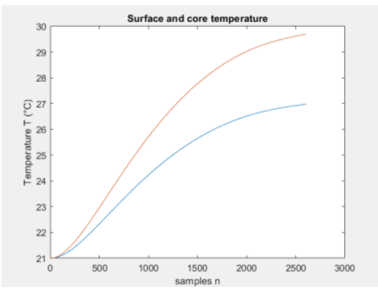
6 – Follow-up



7- Results

- **Electro-thermal model simulation results**

Simulation of surface and core temperature



Visualization of surface temperature simulation with experimental samples

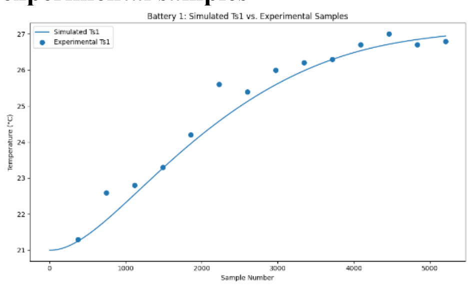


Table of value errors of final surface temperature sample simulation vs experimental

Batteries	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Error	**0.53%**	**0.29%**	**1.80%**	**2.18%**	**0.45%**	**0.68%**	**4.14%**

- **Temperature Estimation**

4 sensors case

Batteries	**3**	**4**	**6**
Surface Error (ºC)	**0.081**	**0.076**	**0.073**
Core Error (ºC)	**0.478**	**0.473**	**0.461**

3 sensors case

Batteries	**2**	**3**	**4**	**6**
Surface Error (ºC)	**0.096**	**0.098**	**0.093**	**0.089**
Core Error (ºC)	**0.627**	**0.586**	**0.580**	**0.566**

2 sensors case

Batteries	**2**	**3**	**4**	**6**	**7**
Surface Error (ºC)	**0.118**	**0.118**	**0.113**	**0.109**	**0.117**
Core Error (ºC)	**0.754**	**0.705**	**0.698**	**0.680**	**0.753**

The error values seen are the mean errors of all samples from battery simulation