

ANADOLU ISUZU



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Optimizing Cooling Circuit Lines In Between Batteries and Its Thermal Management Unit For 12m EV Buses





ANADOLU GROUP

Company Overview



ANADOLU ISUZU AT A GLANCE

Operations



Operating in the Commercial vehicle segment with a strong product range , Dealer network + Aftersales service expanded to a big geography

Products



Manufacturing ; Trucks, Light trucks, Buses, Midibuses & Pick-ups With an ambitious export strategy

Milestones



Foundation and Partnership Formation (1984)
Start of Production and Çayırova Plant Launch (1987)
Export Beginnings and International Expansion (1990s)
R&D Strength and Next-Generation Vehicles (Post-2010)
Electric Vehicles and Sustainability-Oriented Transformation (Post-2020)

ÇAYIROVA PLANT

107,500 m² covered, 300,000 m² total production area

185,000 vehicles manufactured

Export to 44 countries

Over 25 different vehicle models



Study Overview

Effective thermal management is essential for battery performance and safety in electric buses. This study aims to **optimize the BTMS** of a 12-meter EV using **1D simulations**.

Key focus areas:

- Coolant line layout

- Flow rate distribution

- Pressure drop balancing

By optimizing pipe diameters and component placement, a more uniform coolant flow was achieved. Simulation results were validated experimentally, with a maximum deviation of 8%.

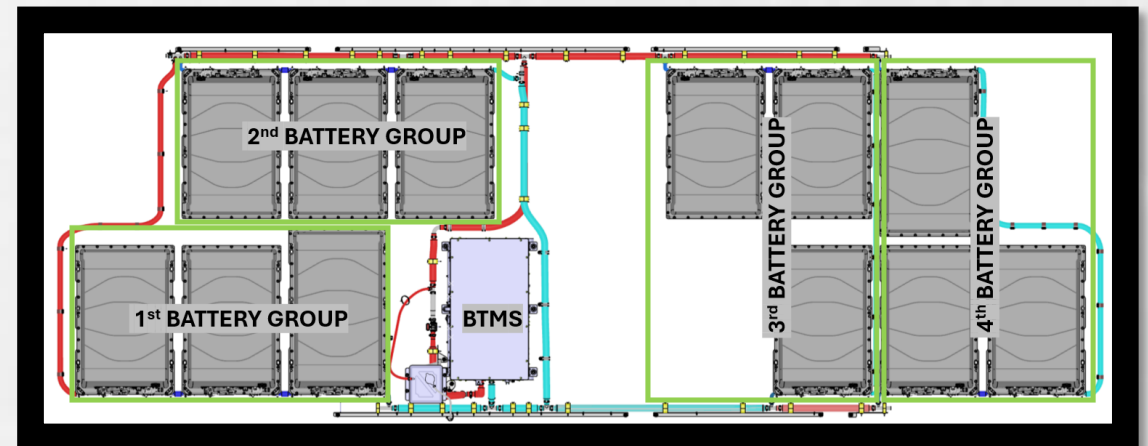
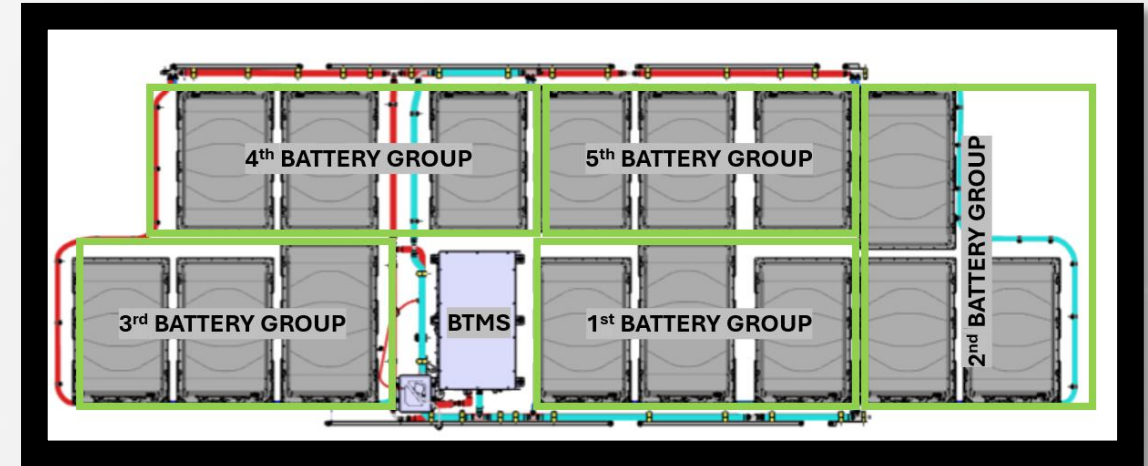
Battery Configuration & Cooling Layout

In the **15-battery setup**, additional modules are **roof-mounted**.

The BTMS features a cooling circuit with

- 5 parallel branches
 - 3 serial connections
- ensuring effective thermal regulation across all battery packs.

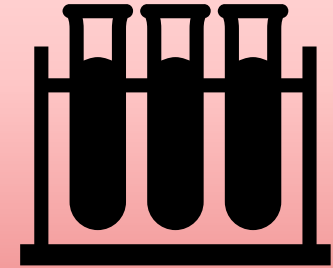
The vehicle supports 12- and 15-battery configurations.



| Test Setup & Conditions

Coolant Properties

- 50/50 antifreeze-water mix used (**BASF G48 Glysantin**)
- Protects down to **-38°C**, raises boiling point to **~105°C**
- Only **distilled or deionized water** allowed (to prevent scale)
- Higher antifreeze ratios may reduce heat transfer



Test Conditions

- Tests performed at **20°C ambient**
- Coolant temperature stable at **19–20°C**, monitored via **CAN Bus**

Flow Measurement Setup

- **Direct battery group measurement** not possible due to space limits
- **Flowmeters** placed at **predefined circuit points**
- Measurements conducted for both **12- and 15-battery configurations**

Flowmeter Placement & Test Points

Sensor Placement Strategy

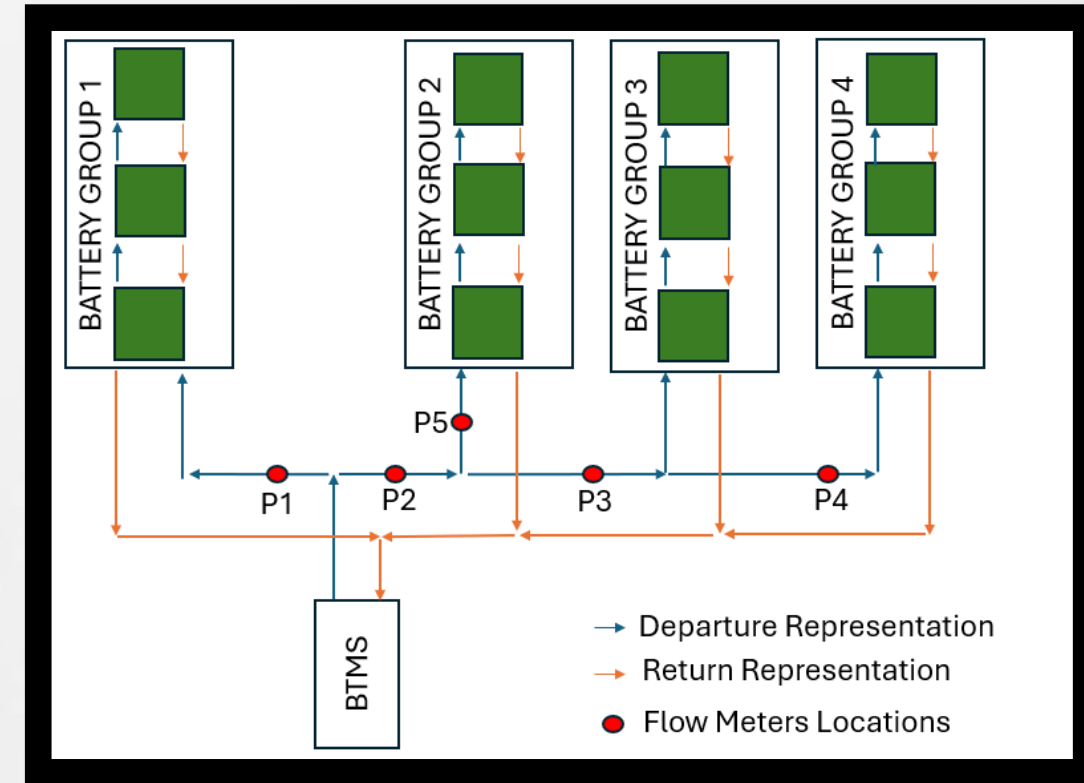
- Flowmeters positioned **close to battery groups** to improve measurement stability
- **Individual battery group measurement** was not possible due to space constraints
- Instrumentation points were selected **before vehicle testing** for reliable data collection

Flowmeter Setup

SM 6020 flowmeters selected for high accuracy in coolant measurement

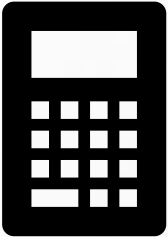
Installed on **straight hose sections** to avoid flow disturbances

Proper **alignment** ensured — no bends or obstructions



KULI Modeling Approach

Vehicle thermal management was modeled using **KULI**, a 1D simulation tool by STEYR Engineering. This software helps optimize both **component-level** and **system-level** thermal performance.



In the model:

Flow rates were monitored at each component inlet.

Pump and battery dP-Q curves were integrated using supplier data (confidential).

The coolant flow splits at the pump outlet and branches toward battery units.

To improve accuracy:

All elbows, bends, junctions, and separators were individually added.

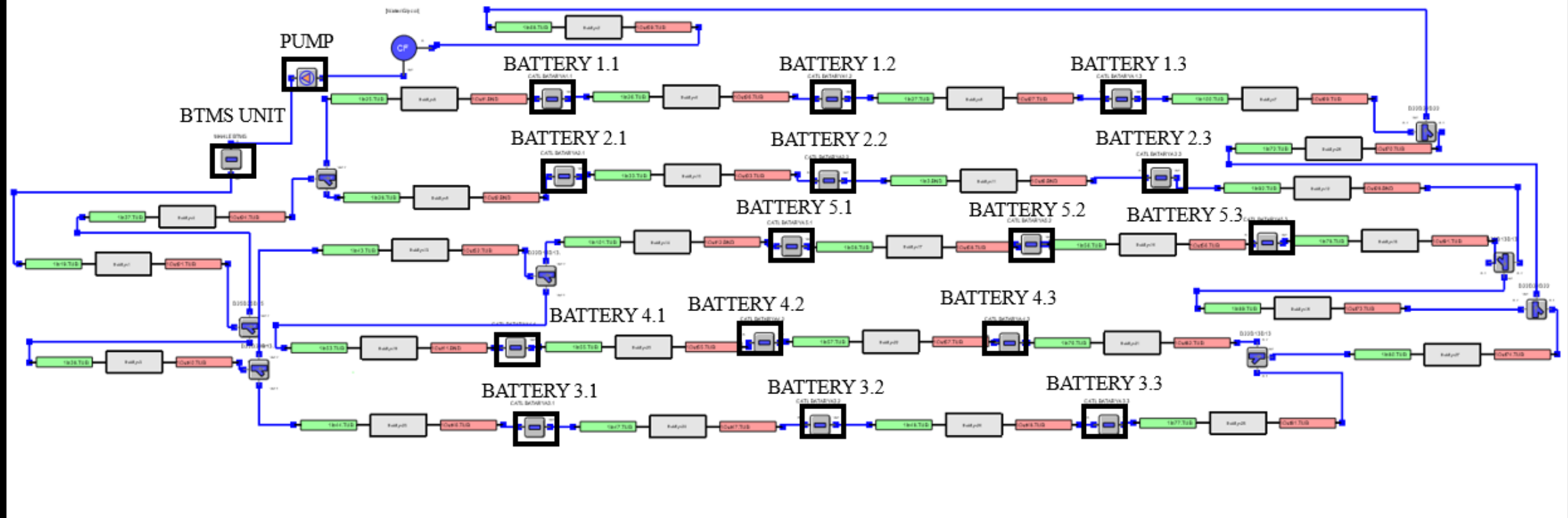
Both component pressure drops and line losses were considered.

This approach ensured a realistic prediction of flow distribution and pressure losses across the system.



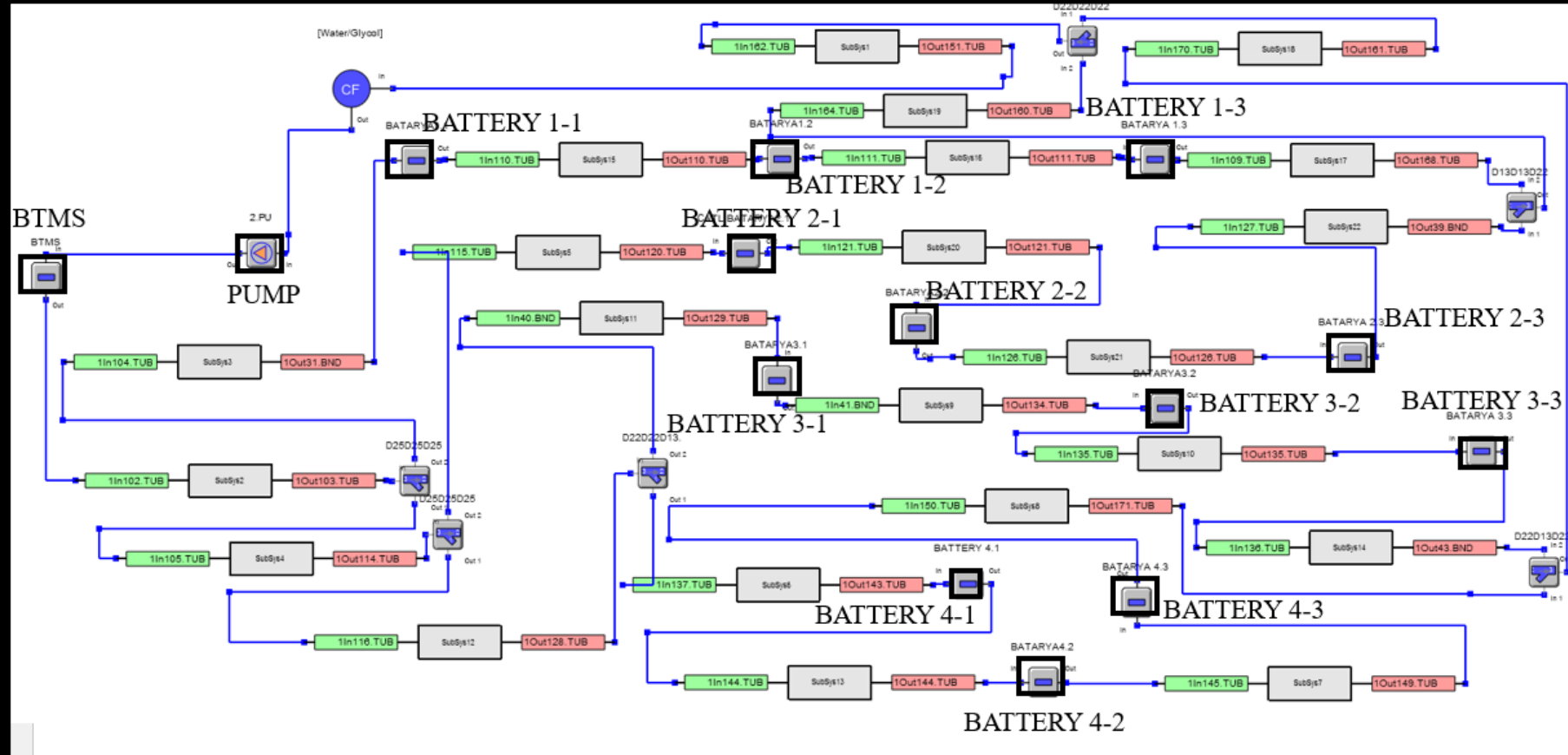
1D KULI MODELS

15 BATTERIES MODEL VIEW



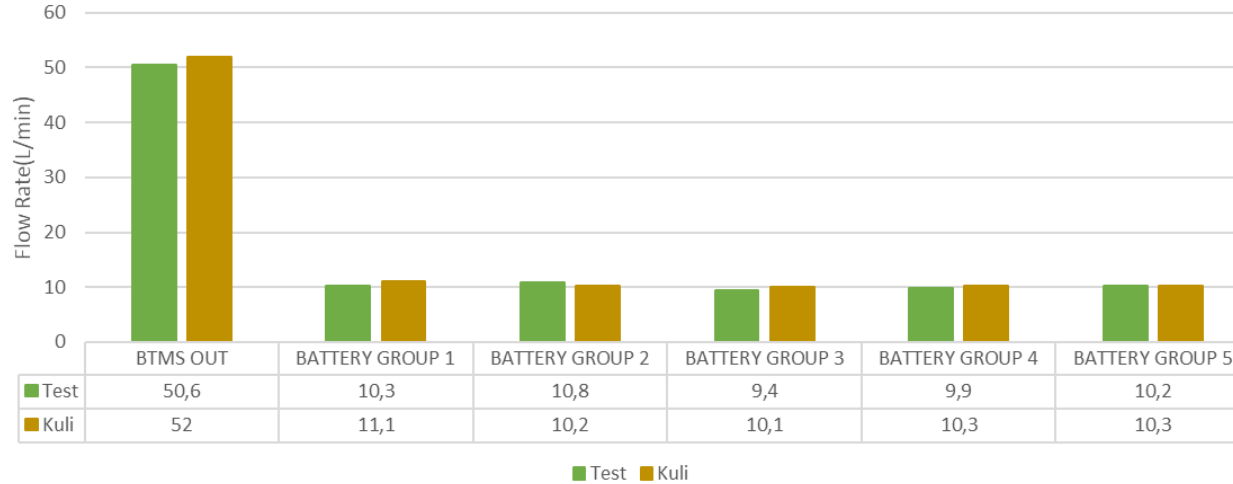
1D KULI MODELS

12 BATTERIES MODEL VIEW

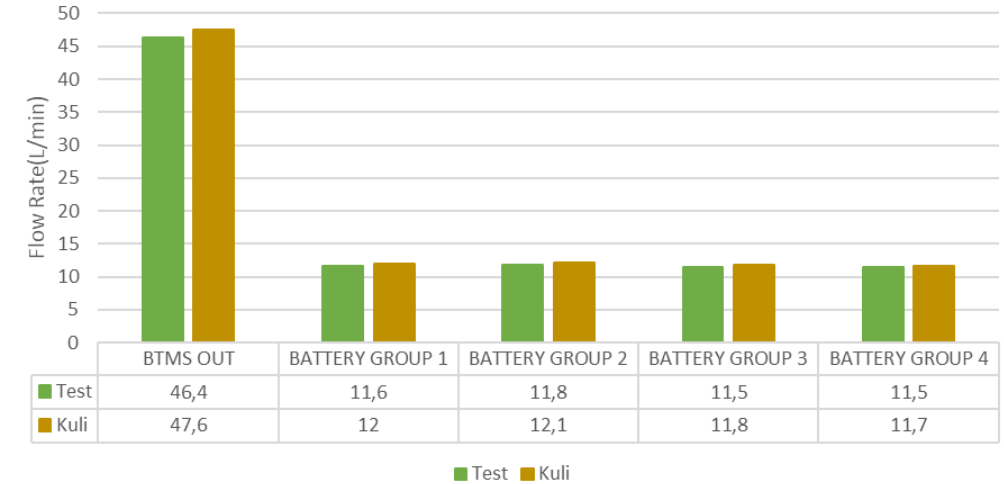


Validation

FLOW RATE OF THE BATTERIES FOR 15 BATTERY OPTION



FLOW RATE OF THE BATTERIES FOR 12 BATTERY OPTION

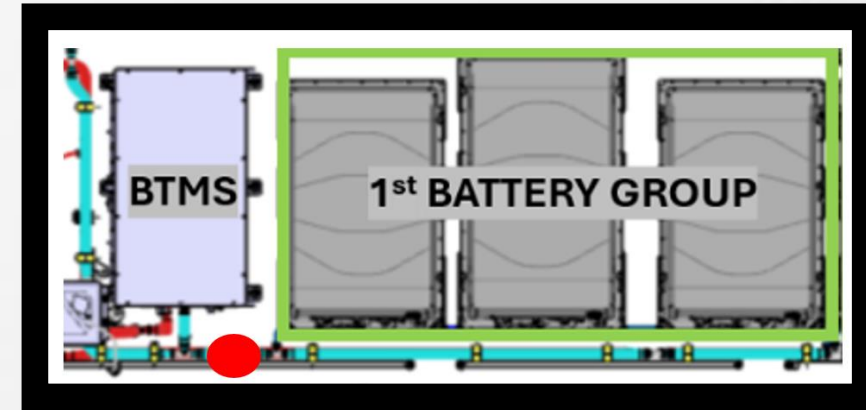


➔ In the **12-battery configuration**, coolant flow was well-balanced, with an average of **11.6 L/min** per group. The variation between groups was minimal (**max 0.3 L/min**), indicating **high uniformity**.

➔ All groups exceeded the **10 L/min minimum**, except **Battery Group 3** in the **15-battery setup**, which had **9.4 L/min** — slightly below the target.

Validation

- The **largest deviation** between simulation and test results occurred at **Battery Group 1** in the 15-battery setup.

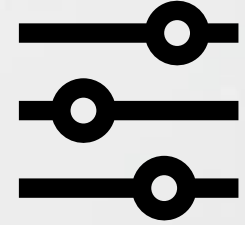


- This was likely due to **pressure losses from flow meters** (the red-marked point in the image), which were **not included in the KULI model**.

- The **placement of flow meters near pipe bends** caused **flow disturbances** and **localized pressure fluctuations**, reducing measurement accuracy.

- In future studies, incorporating **sensor-induced losses** and improving **sensor positioning** could enhance correlation between simulation and real-world data.

Final Flow Balance Achieved



In this study, a **fixed-speed pump** was employed, which made **pressure loss optimization** essential for achieving efficient flow distribution. Using **1D simulations in KULI**, improvements were made by adjusting the **hose diameters and lengths** between battery groups. These changes minimized pressure differences and helped achieve a **balanced and sufficient coolant flow** across all battery packs. The final design was evaluated under **physical test conditions**, confirming that the system delivers consistent flow performance without requiring active flow control elements.



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