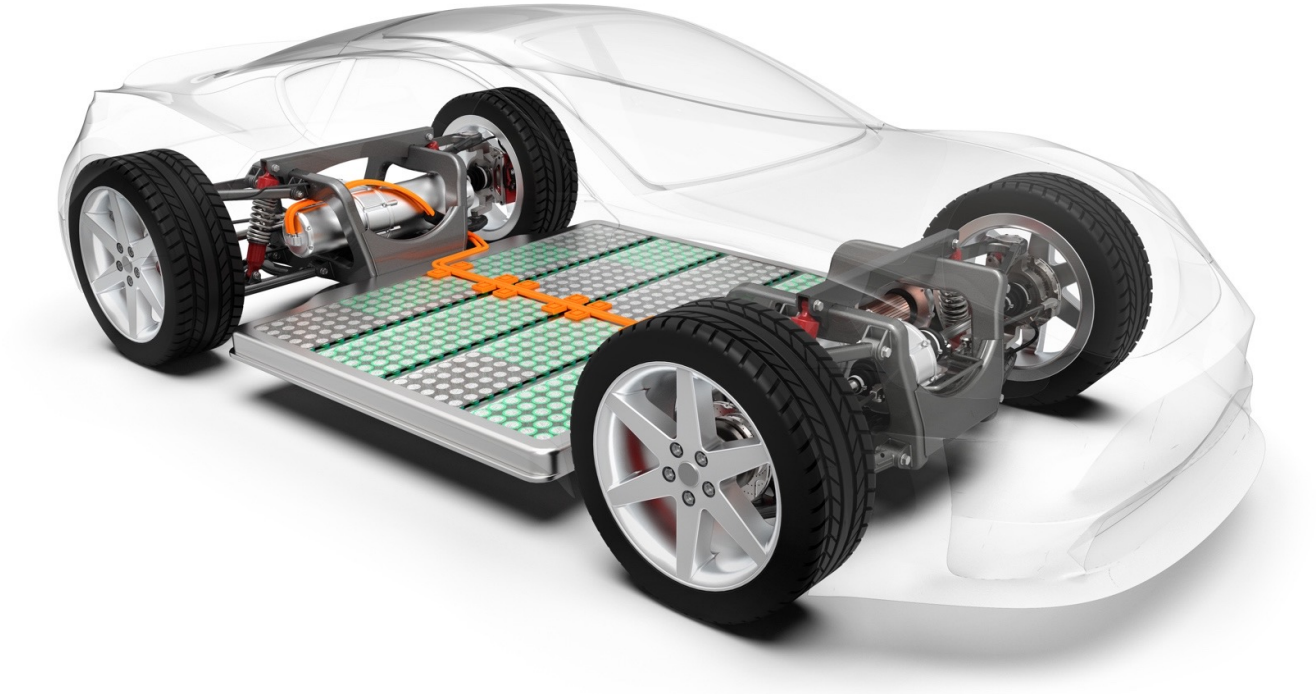
Testing for Ensuring the Functionality, Quality & Reliability of Battery Management Systems, BMS



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Importance of Testing BMS during Design - **Safety**

- BMS ensure battery packs are safe:
  - If Lithium-Ion batteries are used beyond their safe operation, **can result in thermal runaways**.
  - BMS constantly **monitors voltages and temperatures** across individual cells and current across the battery pack.
  - In case of a fault, the BMS must take appropriate **actions to ensure the safety**.
    - *BMS operates a **contactor switch to isolate** the battery pack from the load and the charger.*

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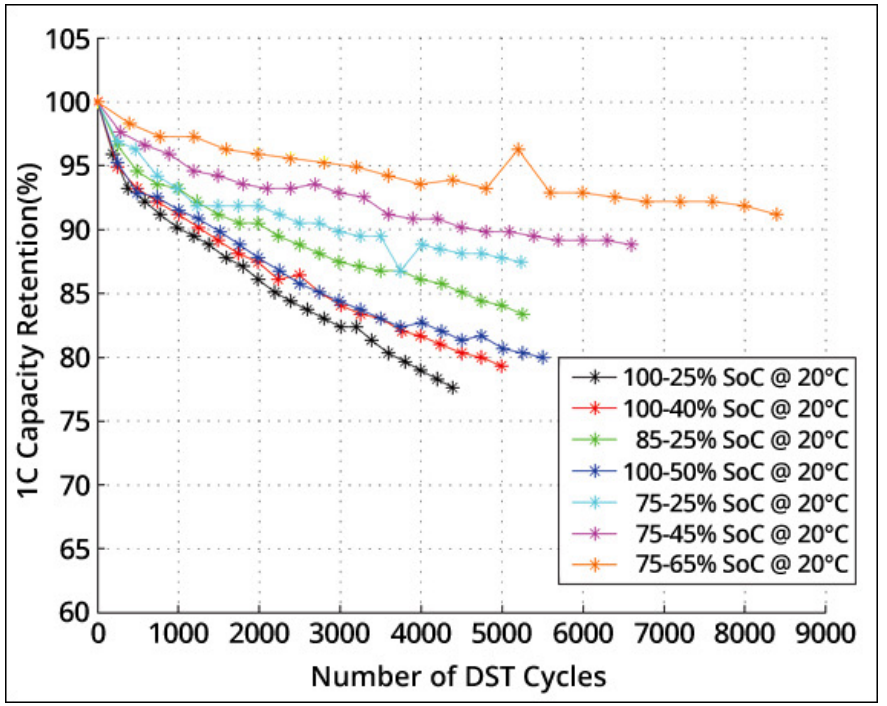
Importance of Testing BMS during Design

- **State-of-Charge (SOC)**, in simple terms is the % of battery.
- Accurate and effective estimation of SOC helps protect the battery, prevent overcharge or discharge, and improve the battery life.

Around 75%-25% and/or 80%-20% is what is recommended by most EV manufacturers



https://batteryuniversity.com/article/bu-808-how-to-prolong-lithium-based-batteries

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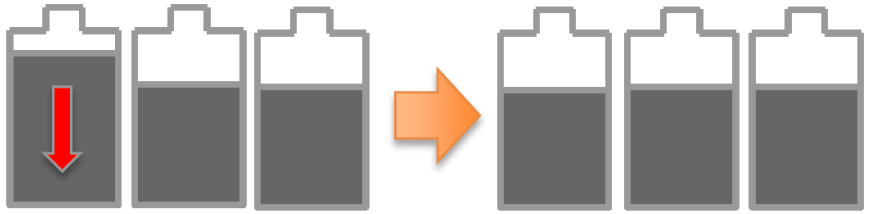
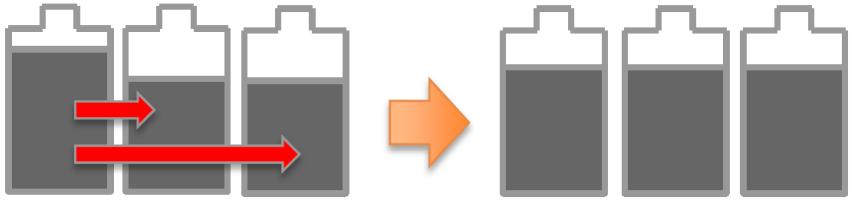
Importance of Testing BMS during Design - **Performance**

- A battery pack comprises several battery **cells stacked together in series** - each cell has its own characteristics.
- To **ensure the overall state of charge** is achieved, it is the BMS ensure all the cells in the pack charge or discharge at the same rate to avoid overcharging and discharging.
- This is achieved by **Cell Balancing.**
- By providing effective cell balancing techniques, the BMS improves the available capacity of the battery pack and **increases the longevity** of battery cells.
- There are two different types of cell balancing techniques.
  - Active Cell Balancing: where excess energy from a cell is redistributed to other cells.
  - Passive Cell Balancing: where the system dissipates the energy of the highest voltage cell in the pack.

Passive



Active



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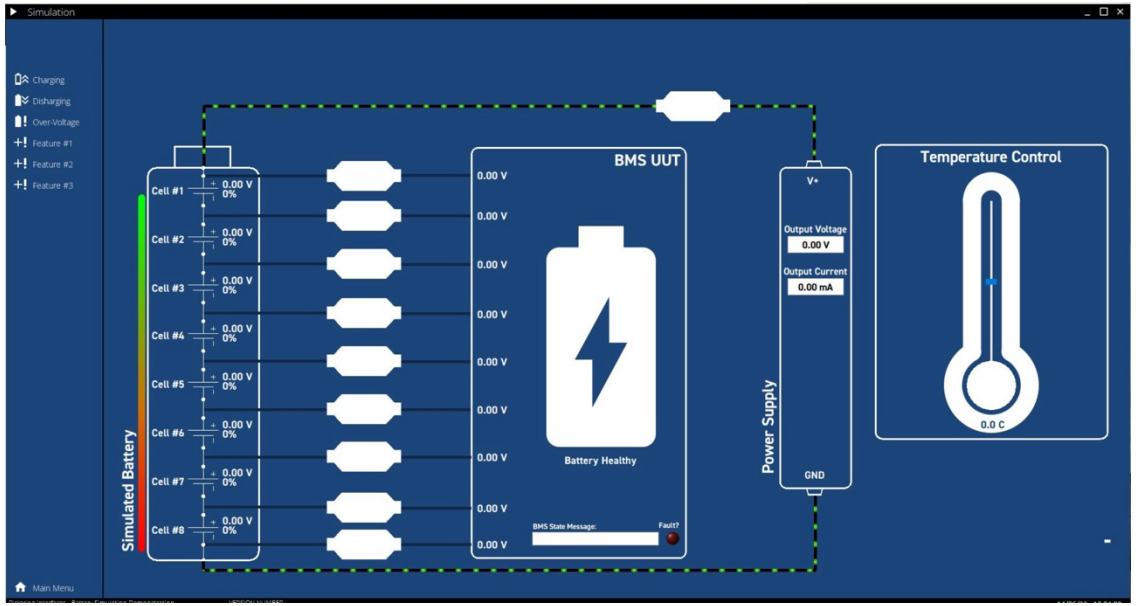
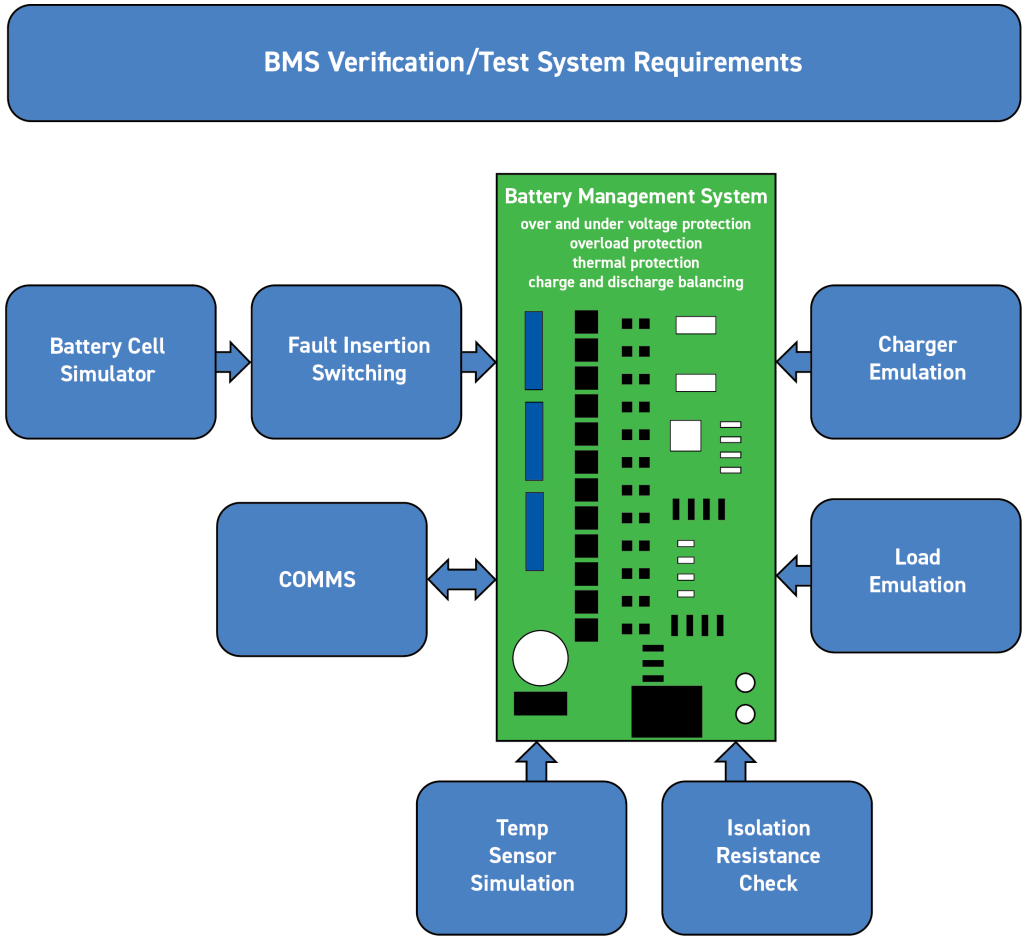
Reason Not use Real World Stimulus?

- **Time to Test**
  - You would need to cycle battery packs.
  - You would need to manipulate real-world conditions.
- **Repeatability**
  - Age and conditions of the ACC affect results.
- **Cost**
  - You would need a setup for every BMS use case, leading to expense in purchase and storage.
  - Setups would need regular maintenance and upgrade.
- **Safety**
  - Taking batteries to extremes could cause catastrophic failure.
  - Battery Stacks are heavy and cumbersome.



What May Need Testing/Simulating? (Hardware-in-the-Loop (HIL)

- **Cells**
  - State of charge
  - Charging
  - Discharging
- **Sensors**
  - Temperature of Battery Stack
- **Isolation**
  - Floating system
- **Communication**
  - Protocol
- **Connectivity**
  - Incorrect wiring



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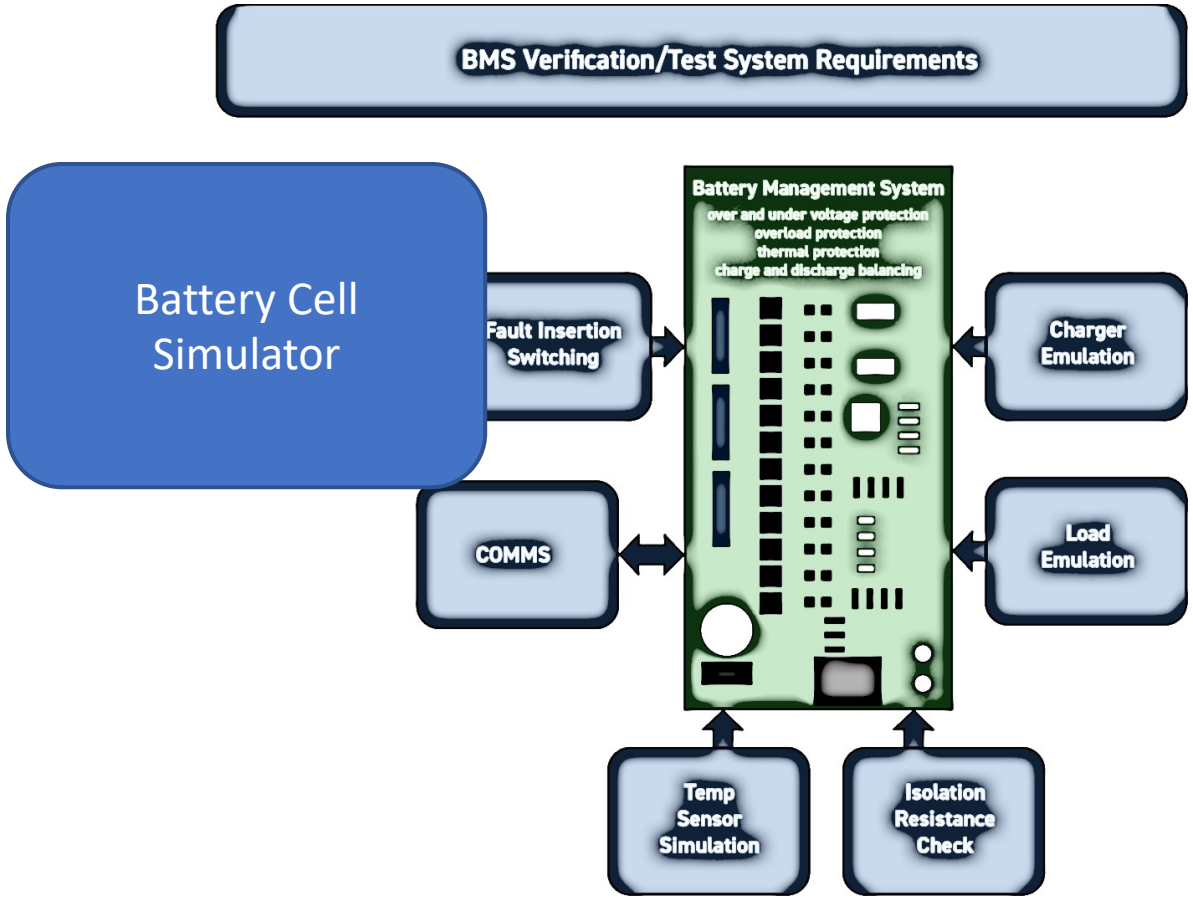
Battery **Cell** Simulator

- **Simulates each cell's voltage** and current output, with current sink to emulate cell charging.
- Programmable over **full cell range** with required precision.
- Cells **stackable**, with voltage isolation of full stack V.
- Ideally **report Voltage & Current** of each cell.
- Each cell has independent remote **sense connections**.



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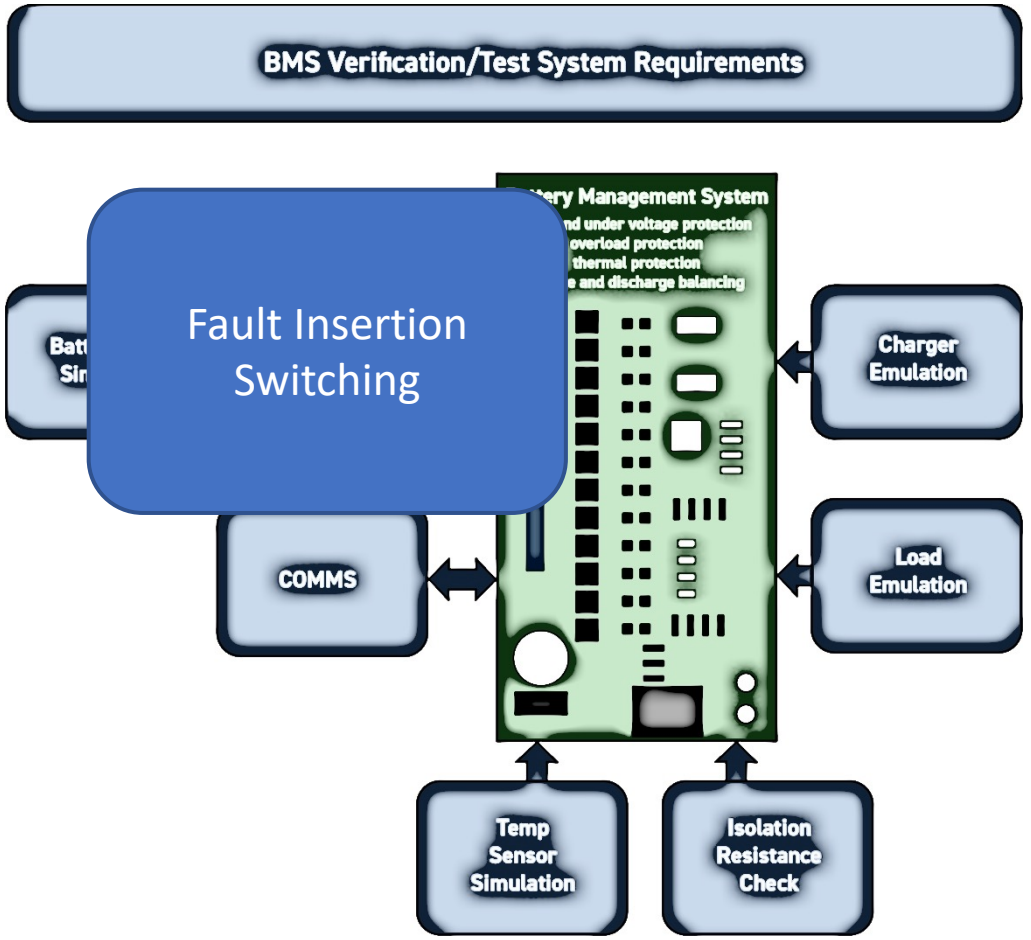
Fault Insertion Switching

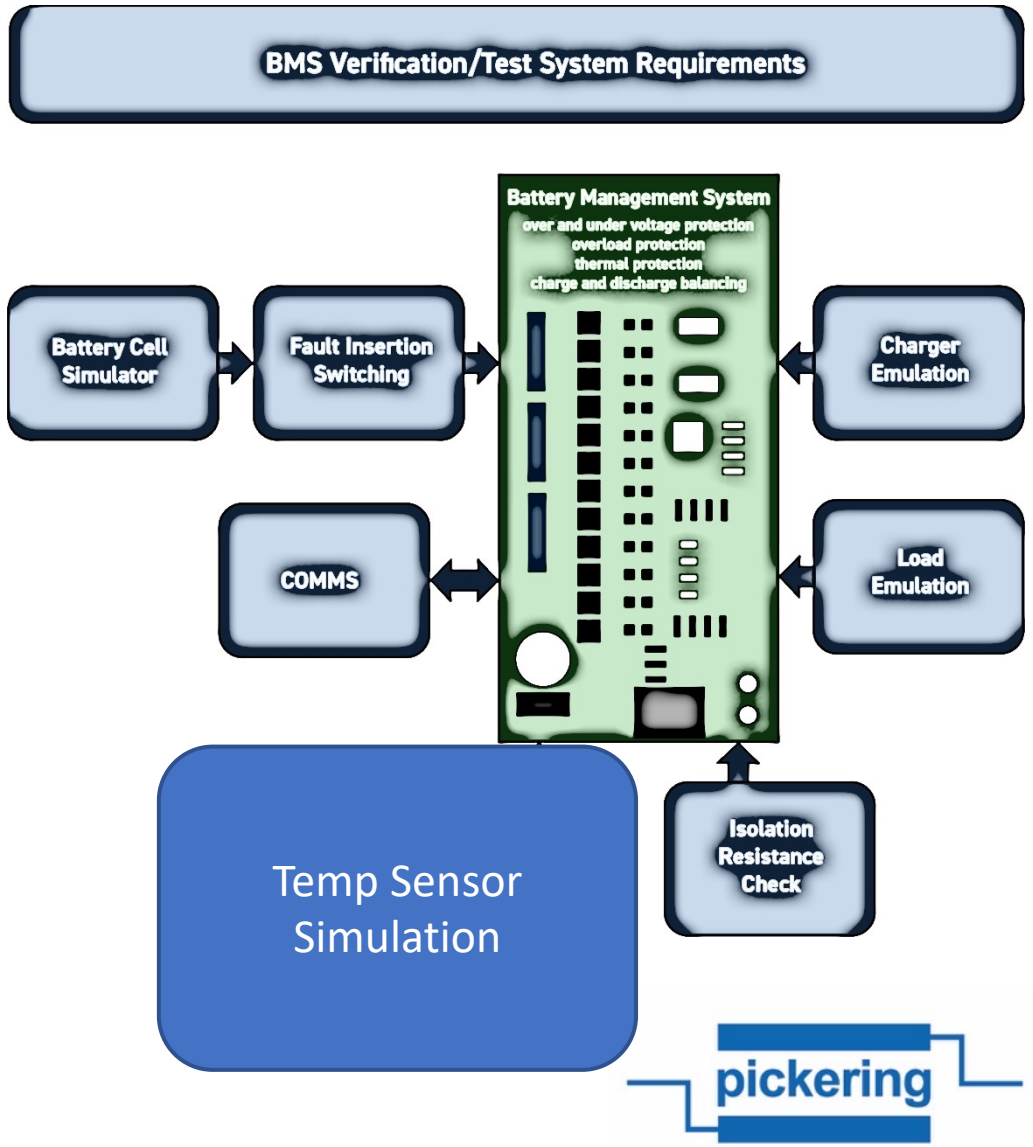
- Simulates **shorts** and **opens** on each battery cell output and **wiring faults** between cells and BMS to verify BMS responses.

- Ideally simulate **polarity reversal** on each cell to simulate manufacturing errors.



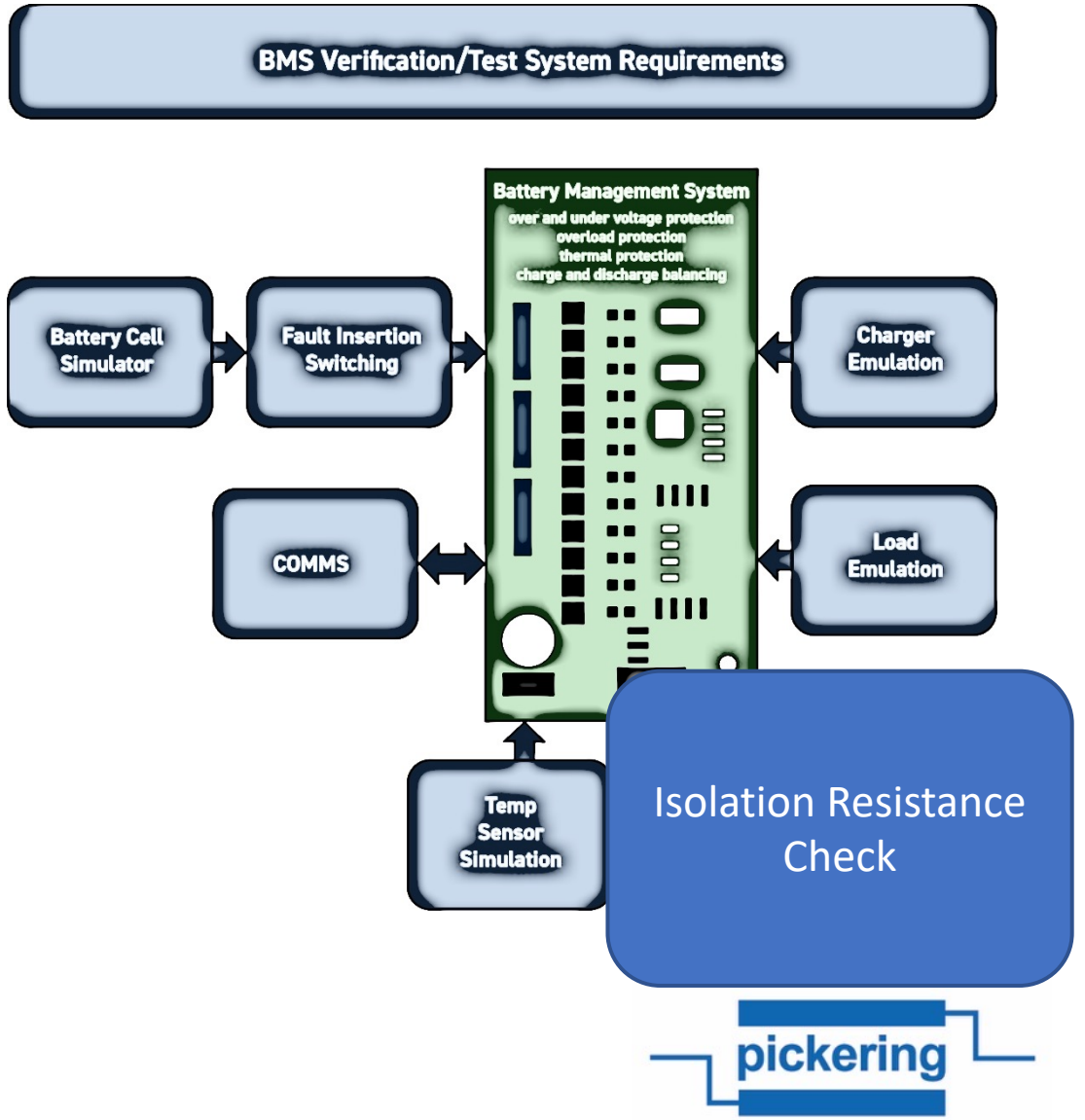
Temperature Sensor Simulator

- Simulates inputs to BMS from remote temperature sensors, e.g., RTDs and thermocouples.
- Programmable to verify BMS **response to temp changes**.
- Ideally **simulate shorts & opens** on each sensor.



Isolation Resistance Simulator

- For BMS with **Isolation** monitor.
- Programmable high resistance with stack voltage standoff.



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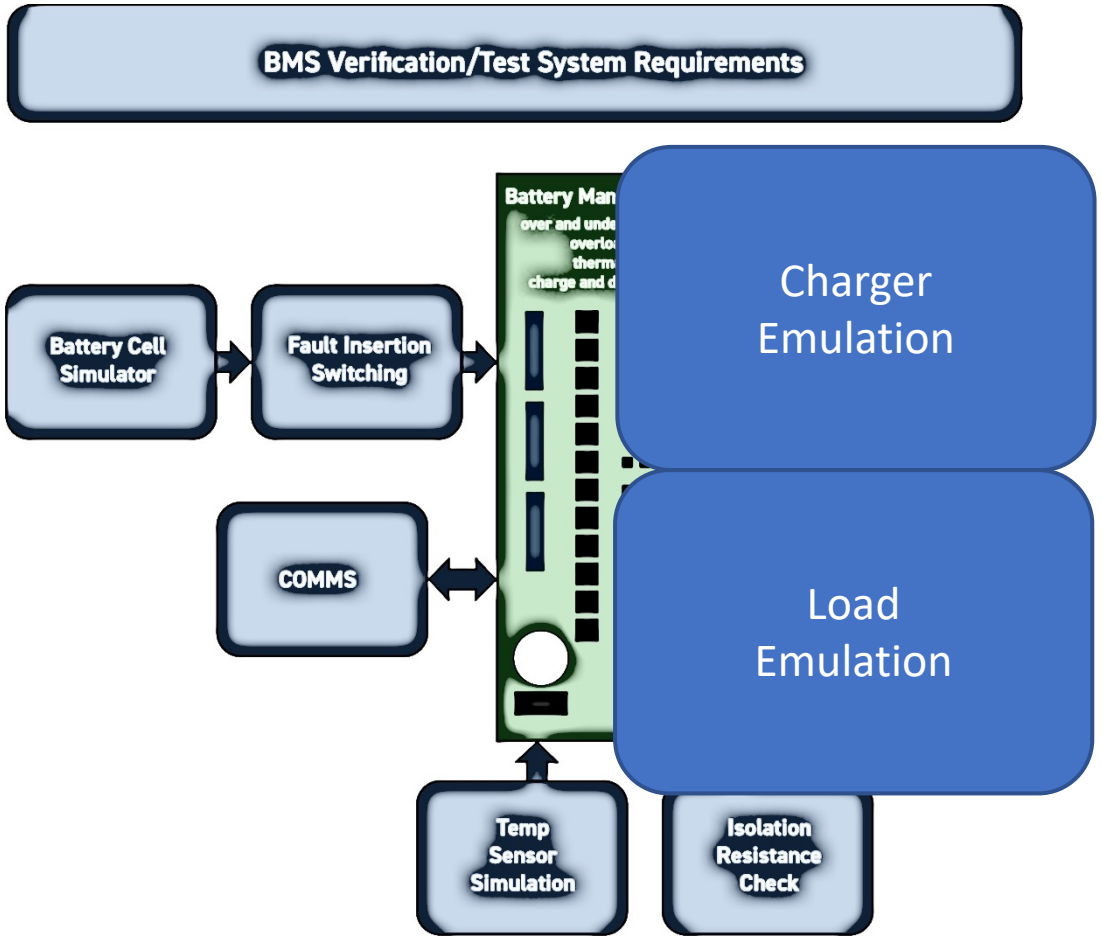
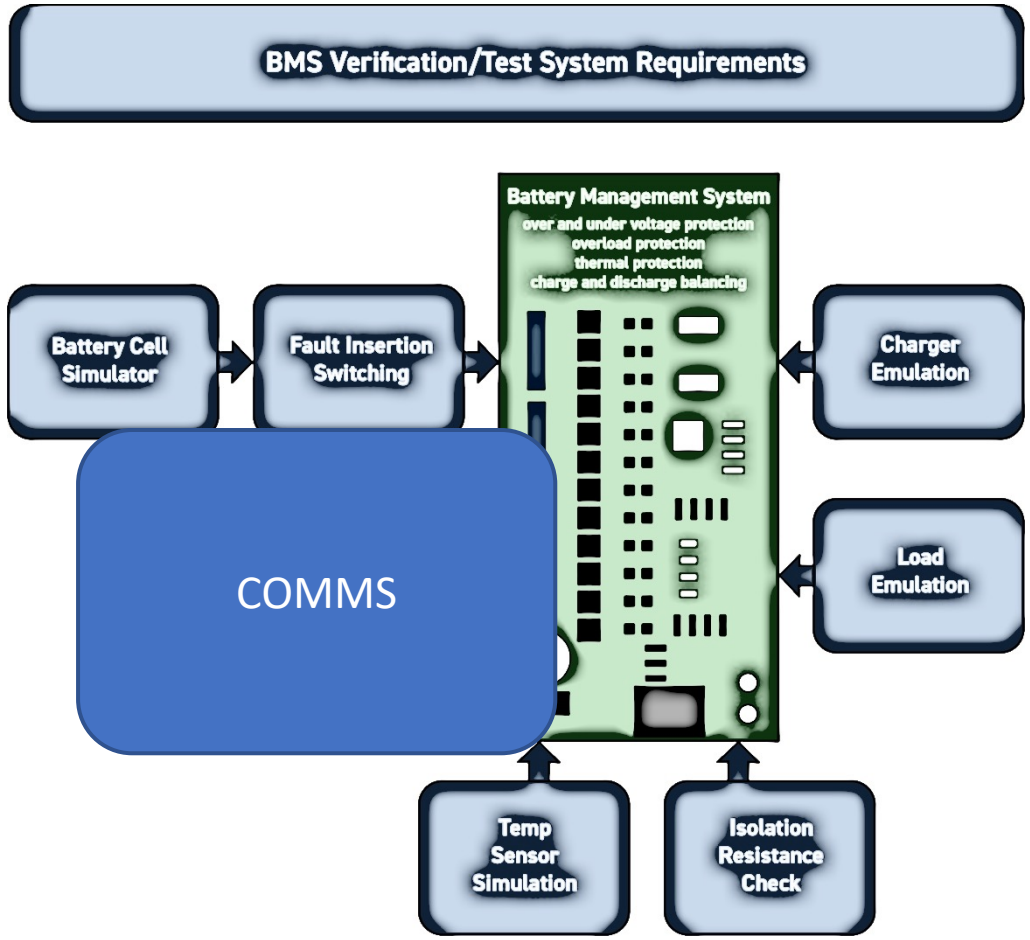
Charger & Load Emulation

- Programmable **source** to emulate charging current coming into BMS.
- Programmable resistive **load** to emulate Battery Stack loading.



COMMS

- Send commands to BMS and monitor status outputs.
- Typically CAN format to emulate communications with vehicle ECU.



Flexible PXI-based BMS Test System

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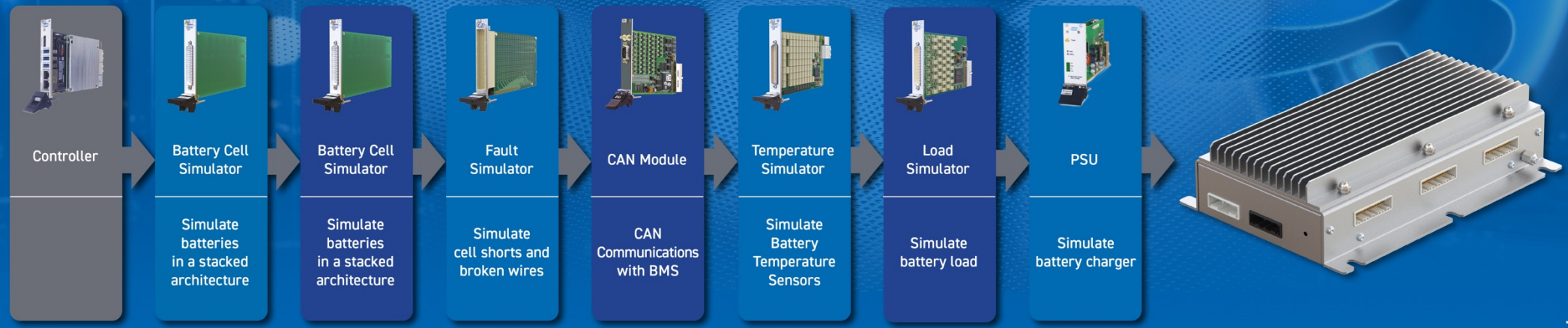

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Small System Example

- Simple BMS System includes:
  - Battery Simulation Module
  - Programmable Resistor Module
  - RTD Simulation Module
  - Fault Insertion Module
  - Source Measurement Unit (SMU)
  - Contained in a PXIe Hybrid Chassis

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In Summary

- Test the BMS real-world conditions (signals).
- Simulating the system has many advantages:
  - Time to Test, Repeatability, Cost, Safety
- Elements needs Simulating / Testing:
  - State of charge (SoC), Charging, Discharging, Sensors, Isolation, Comms, Connectivity
- Using an industry-standard modular platform like PXI has many advantages:
  - Increase test throughput, Lower cost, Lower system redesign time, Flexibility in both hardware & software, Support

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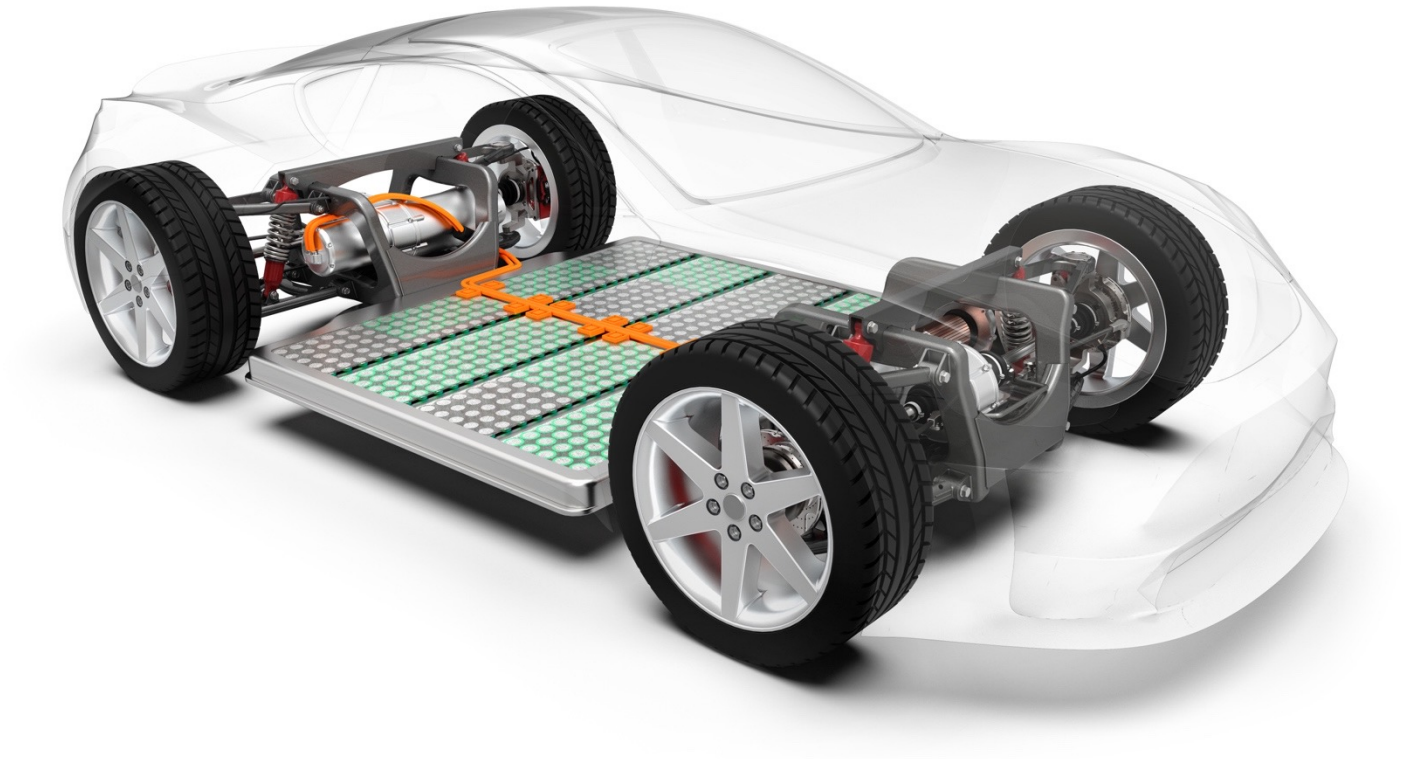
Thank you



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