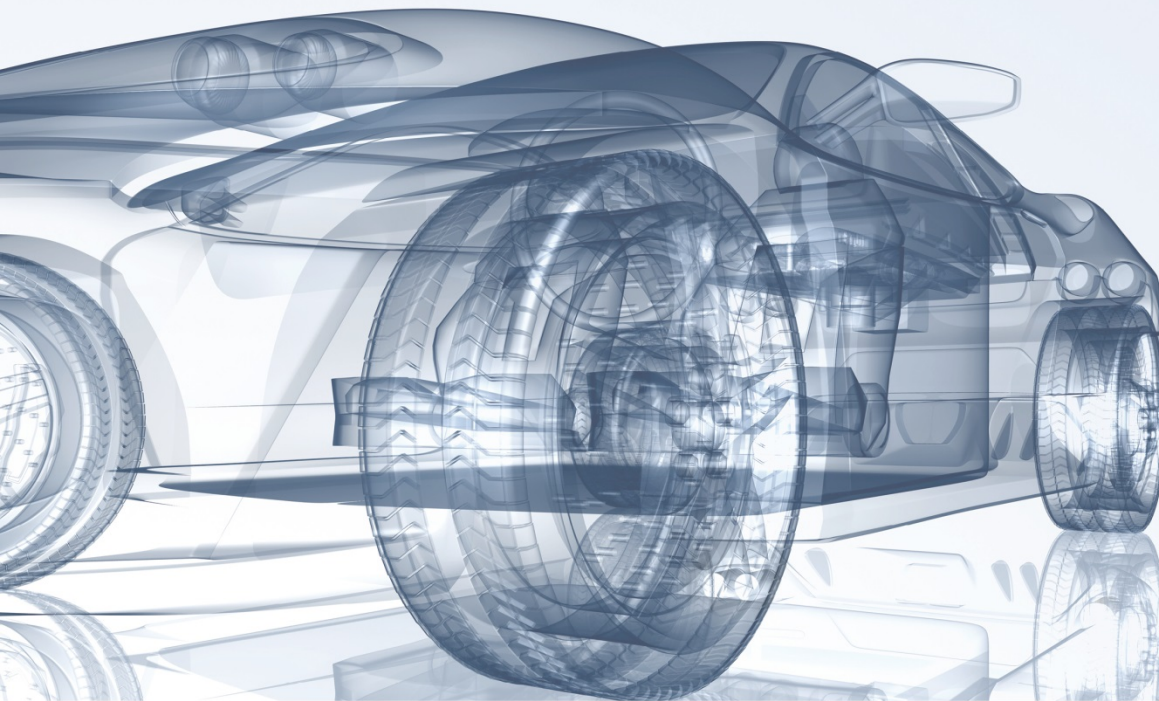


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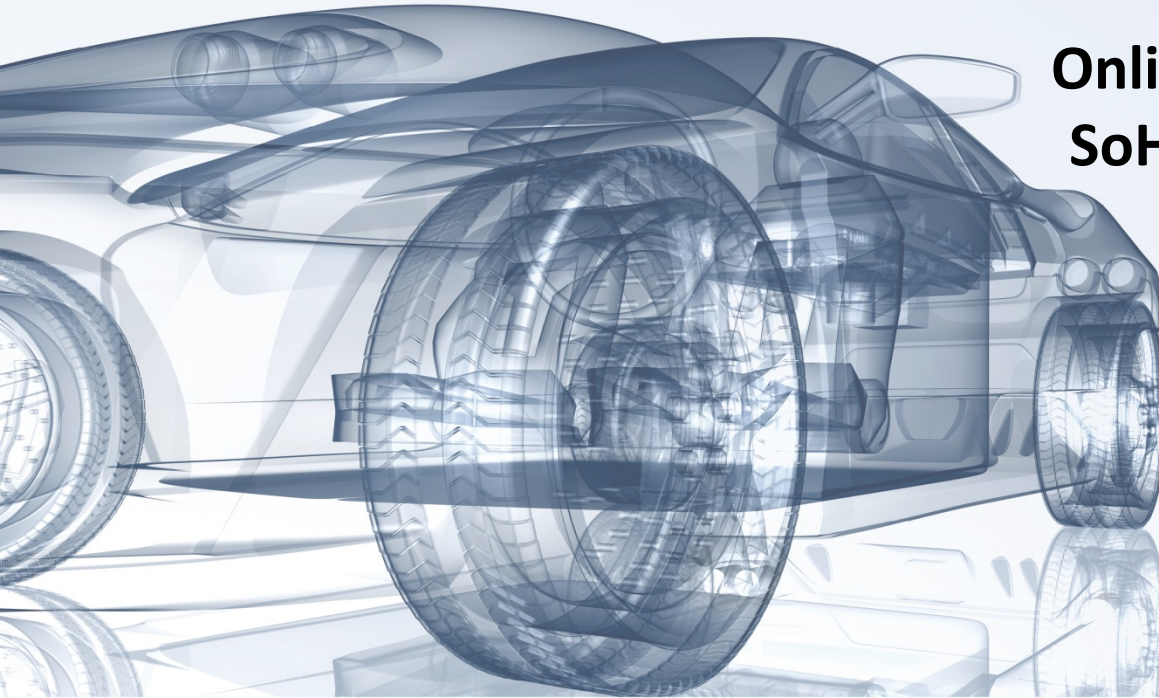
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Online and BMS Implementable SoH Estimation for Lithium Ion Battery Packs

M. Berecibar^{1,2}, J. Crego¹, I. Gandiaga¹,
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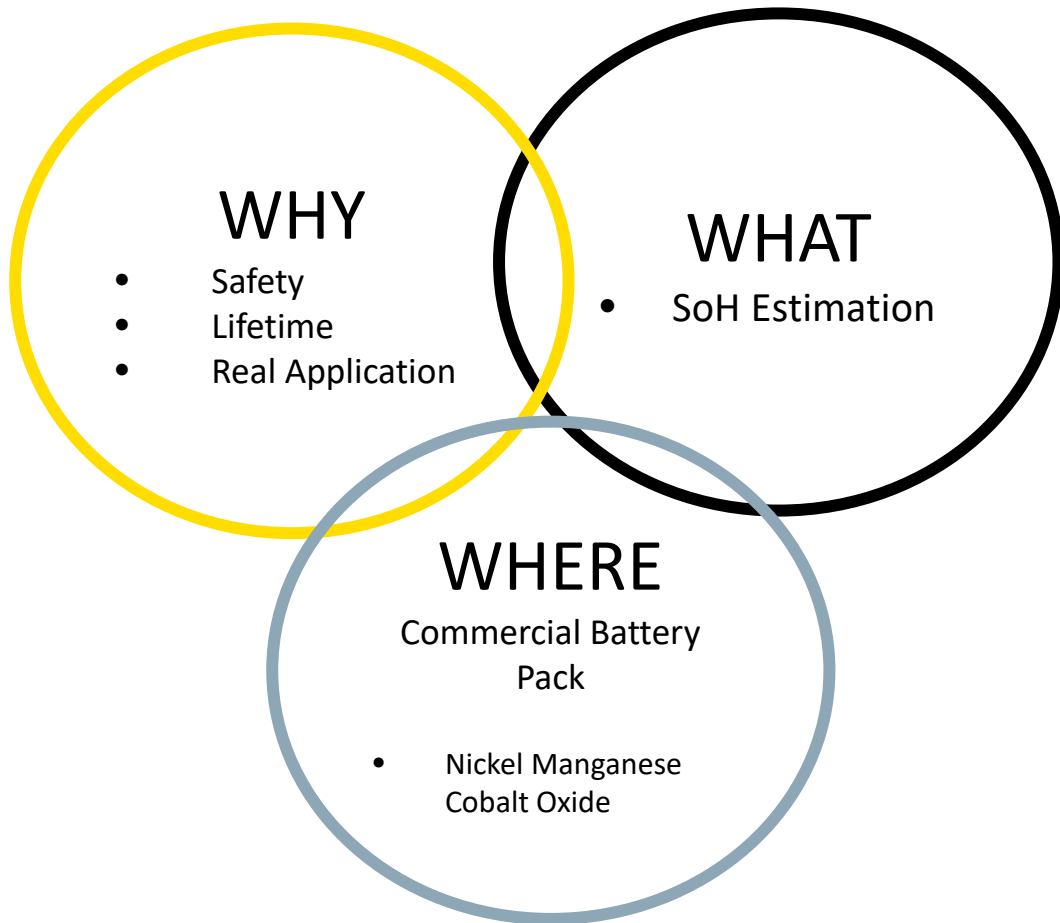
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Research Alliance





Outline

1. Motivation
2. Objective
3. Algorithm
 1. Tested cells
 2. Algorithm basis
4. Results
 1. Cell Level
 2. Battery Pack Level
5. Conclusions & Future Work



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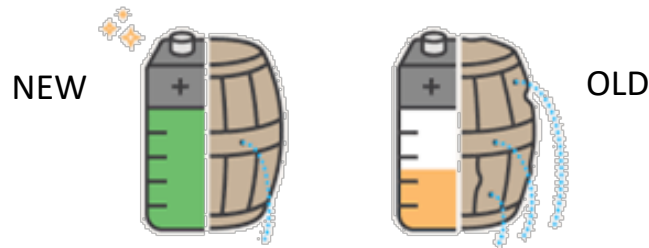
State of Health is the ability of a battery to store energy relative to its initial or ideal conditions

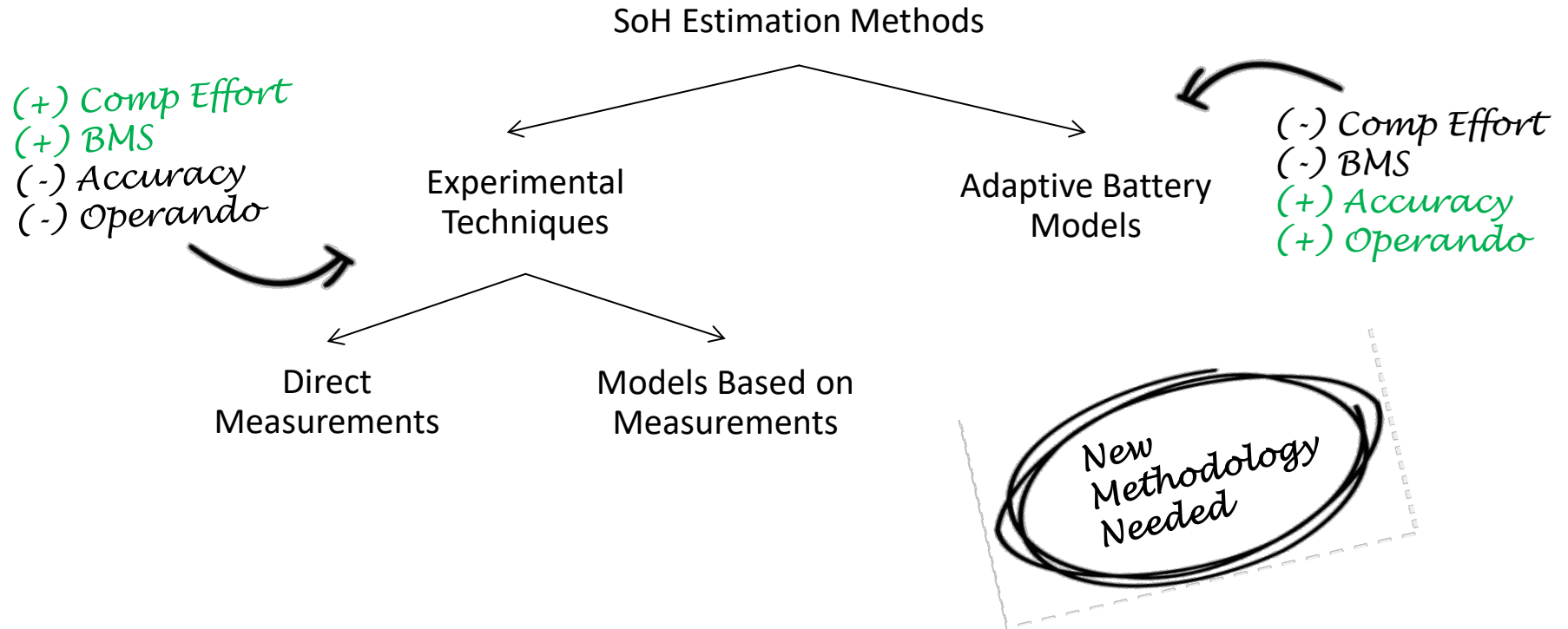
- 100% means the battery is fresh.
- 80% the battery is considered not usable for an Electric Vehicle and should be removed.

Why estimate the SoH?

- Recognize battery degradation.
- Prevent a possible failure.

OLDER BATTERIES LOSE POWER FASTER





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BMS Implementation

- Low computational effort
- Real application

EoL Detection

- Alarm
- User Awareness

Error <1%

- Accurate
- Reliable
- Precise

Application always available

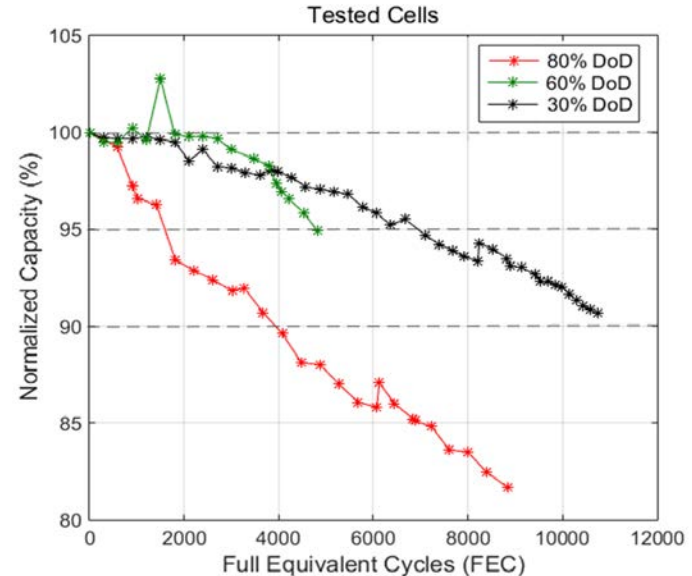
- Customer Needs
- Energy Efficiency

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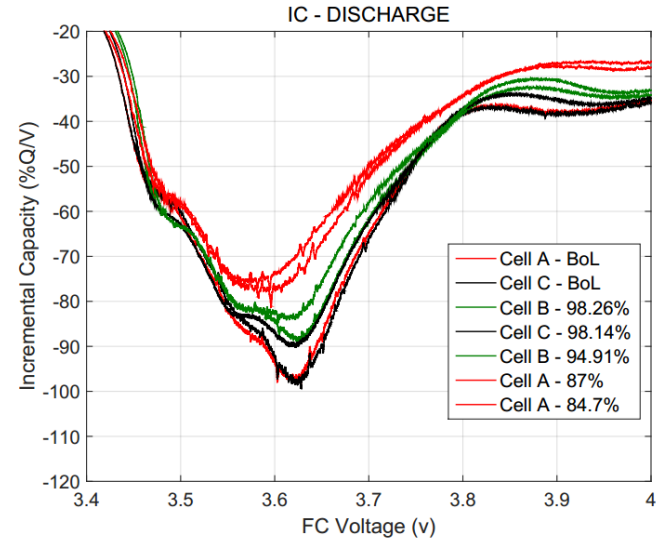


- Nominal Capacity: 40Ah
- Anode: graphite (G)
- Cathode: $\text{LiNi}_{1-x-y}\text{Mn}_y\text{Co}_x\text{O}_2$ (NMC)
- Tested temperature: 25 °C
- Depth of Discharge (DoD):
 - 80% DoD
 - 60% DoD
 - 30% DoD
- Every Cycling Test:
 - Capacity test
 - Complete charge and discharge at C/5 (to obtain the IC curves)



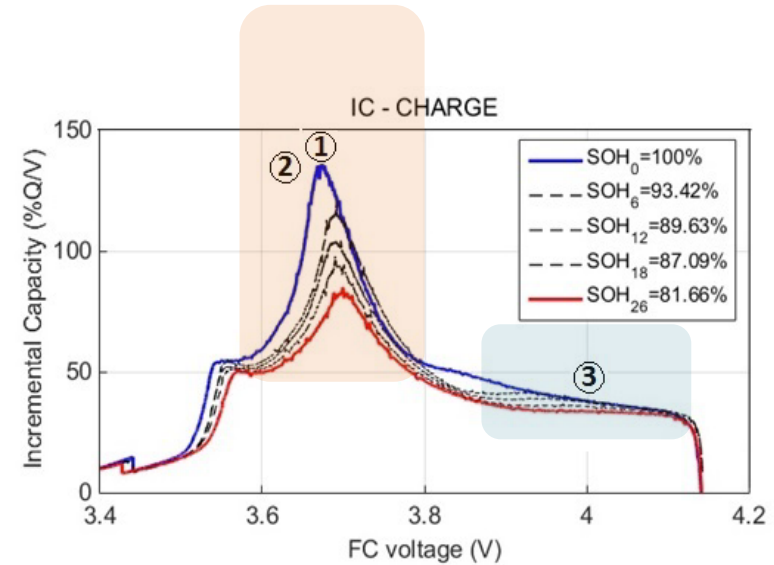
- Incremental Capacity Curves

- Quantify the Degree of Degradation of a cell
- Reveal Battery Degradation Mechanisms
 - Loss of Lithium Inventory
 - Loss of Active Material
 - Internal Resistance Increment Detection



- Features of Interests

- Detection of FoI 1,2
 - Loss of Lithium Inventory
- Detection of FoI 3
 - Loss of Active Material in the Positive Electrode
- Algorithm detecting both location points
- Linear Regression algorithm
- Easy, Fast, Accurate



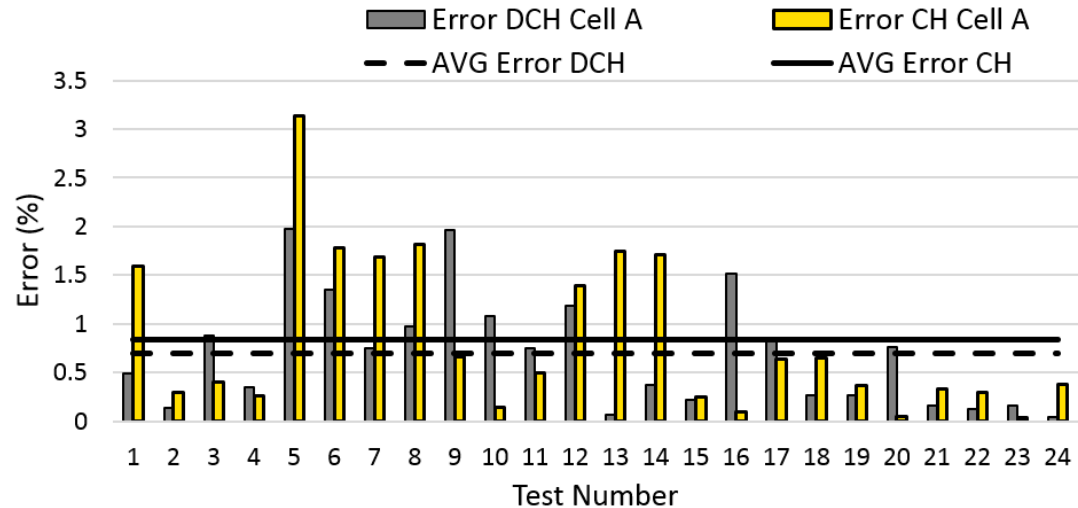
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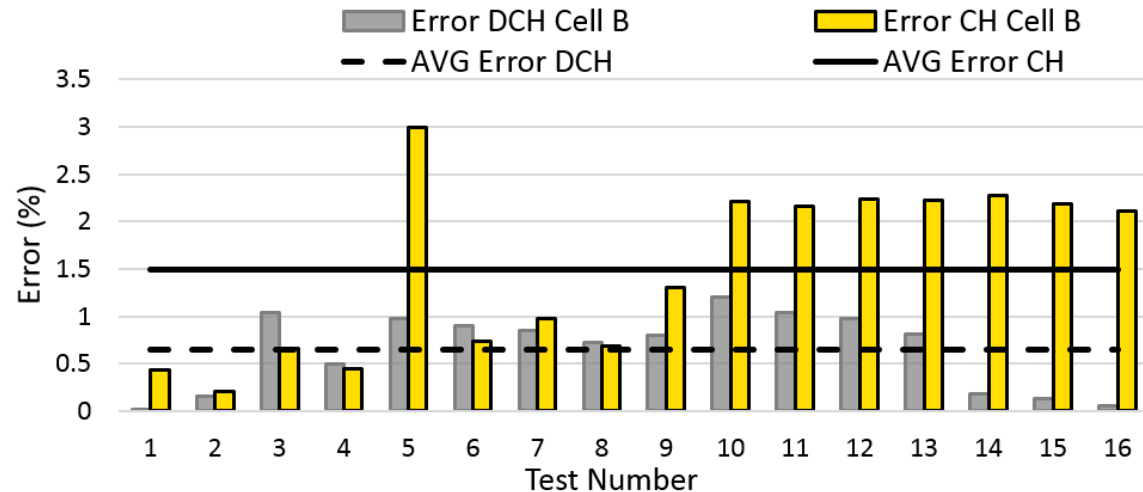
• Cell A

- 80% DoD
- 24 different states
- Until a 80% SoH
- Average Error DCH: 0.67%
- Average Error CH: 0.84%



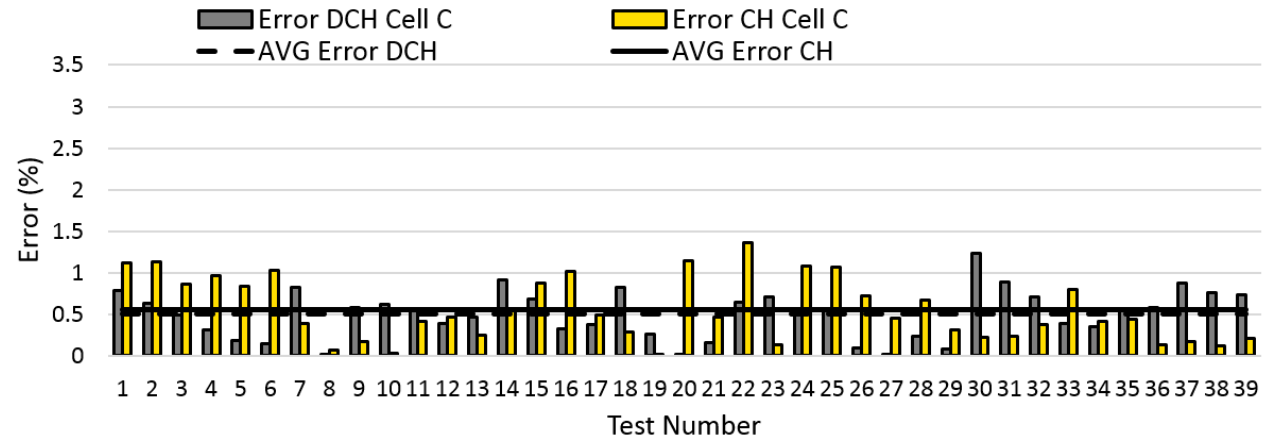
• Cell B

- 60% DoD
- 16 different states
- Until a 95% SoH
- Average Error DCH: 0.65%
- Average Error CH: 1.49%

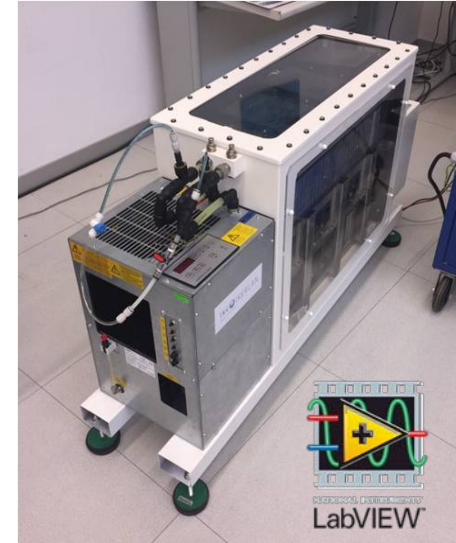
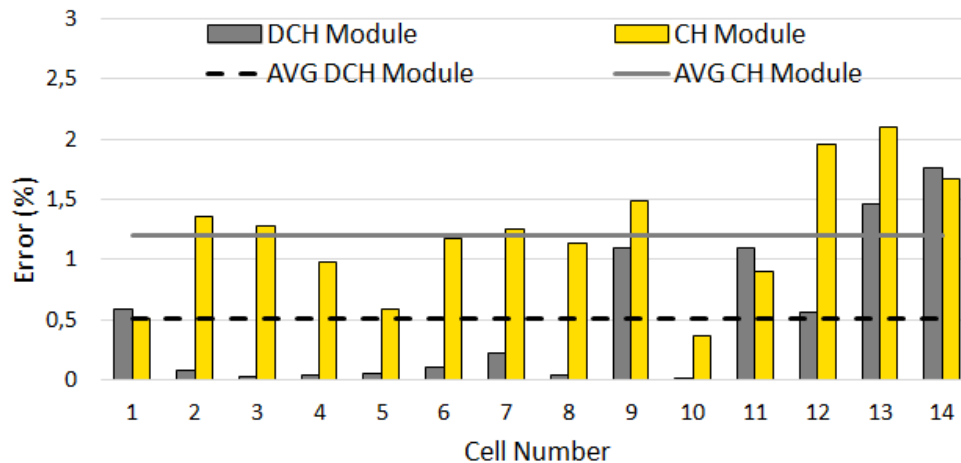


• Cell C

- 30% DoD
- 39 different states
- Until a 90% SoH
- Average Error DCH: 0.49%
- Average Error CH: 0.55%



Validation results: Charging and Discharging



✓ BMS implementable

✓ EoL detection

✓ Avg Error 1.2%

✓ Apl Always Available

✓ Cell & BP level

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BMS Implementation 	EoL Detection 	Accuracy 	Application always Available 	Partial CH & DCH
NEW	NEW	AVG ERROR 1.2%	NEW	NEW

State of Health Estimation

- Diversity of chemistries, cycling, temperatures.
- Production variability, series-parallel connections, balancing.
- 2nd Life applications



Universal Estimation Tool

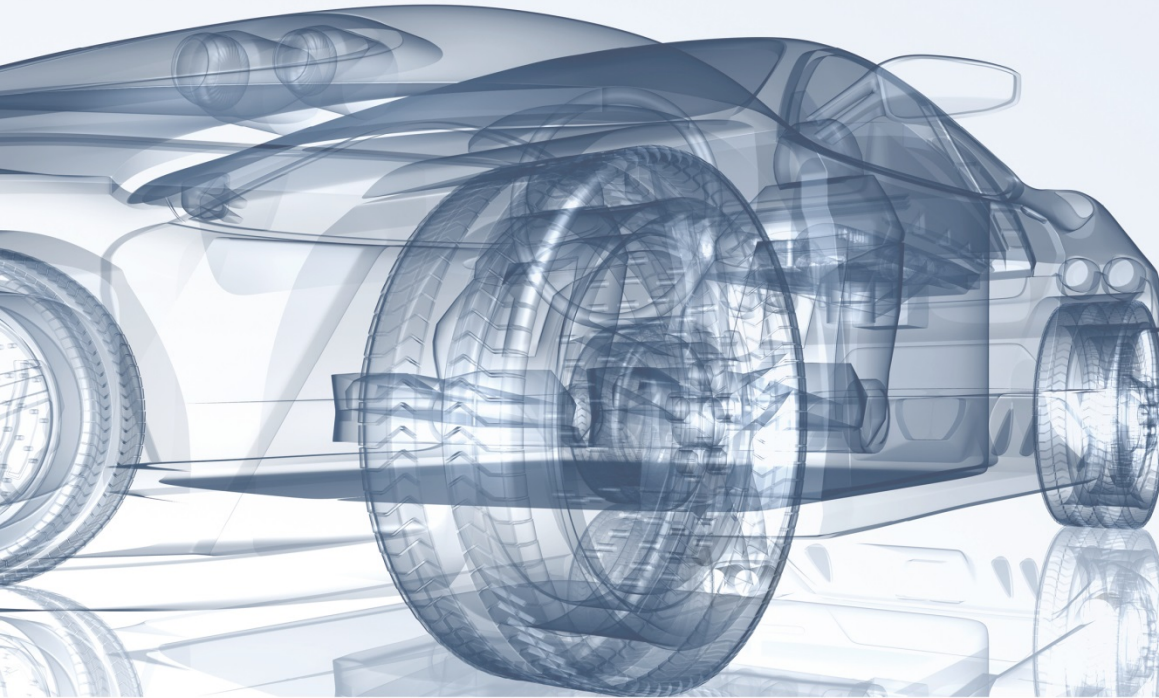


Real Application



Thank you!

Questions?



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