

30 Since 1994

ENGINEERING BATTERIES FOR NRMM DATA-DRIVEN DESIGN

4th June - GT Scandinavian Conference,
Sauli Halonen, Senior R&D Engineer


PROVENTIA

CONTENT

Proventia in brief

Initial battery sizing

Battery pack design

Final product

Conclusion



PROVENTIA IN BRIEF

Founded in Finland

1994

Sales in 2023

54,3 M€

Employees

200

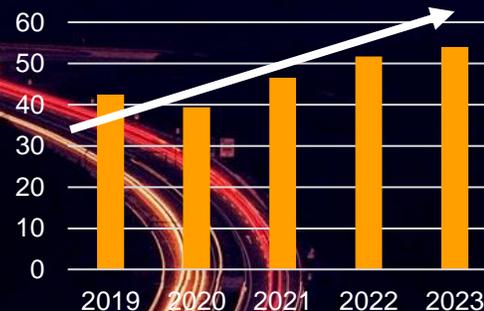
Operating profit in 2023

6,1 M€

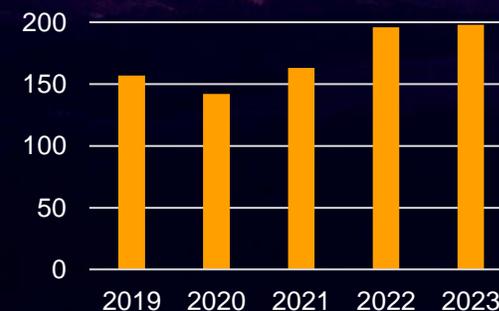
MAIN OWNERS

Head Invest and Evli

Netsales 2018-2022 MEUR



Number of personnel



TECHNOLOGY COMPANY

DEVELOPING CLEANER POWER

OFF-ROAD MACHINERY SYSTEMS & COMPONENTS

EMISSION CONTROL



THERMAL COMPONENTS



BATTERIES



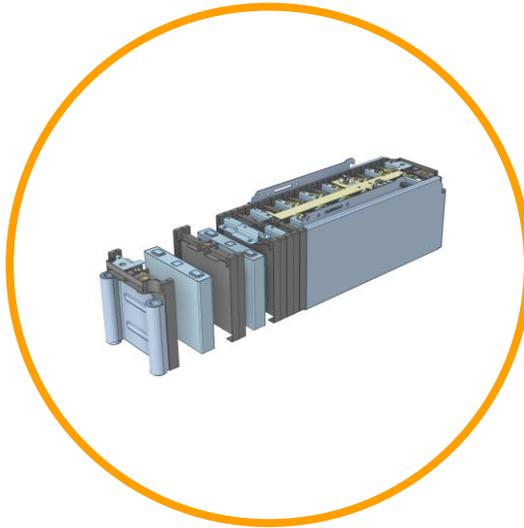
TEST SOLUTIONS



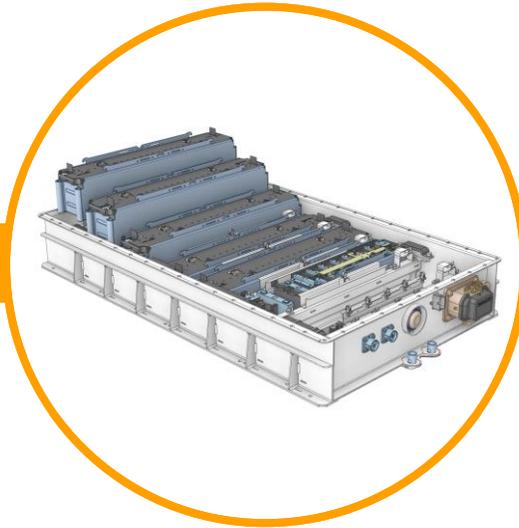
ENGINEERING BATTERIES FOR NRMM

DATA-DRIVEN DESIGN

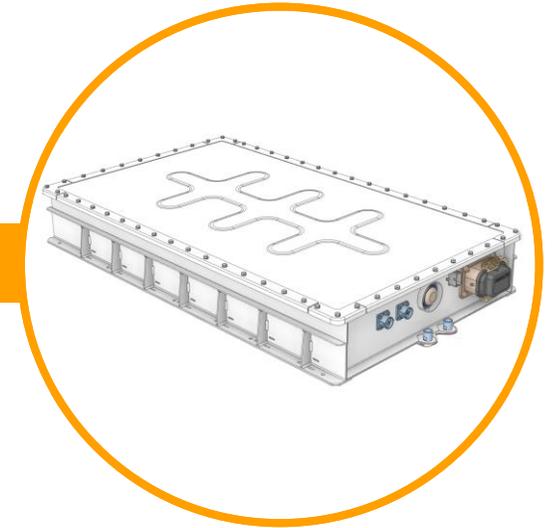
INITIAL BATTERY SIZING



BATTERY PACK DESIGN



FINAL PRODUCT



INITIAL BATTERY SIZING

CUSTOMER DATA

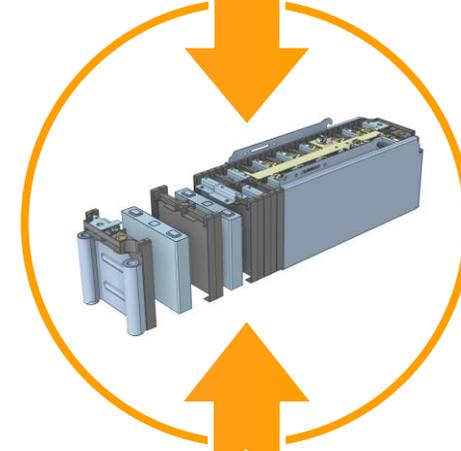
- Load data
- Voltage range
- Power requirements
- Capacity
- Vehicle lifetime

- System electrical requirements
- Battery cell selection
- Initial system layout and system simulation

PROVENTIA

CELL DATA

- Battery specification
- Battery models

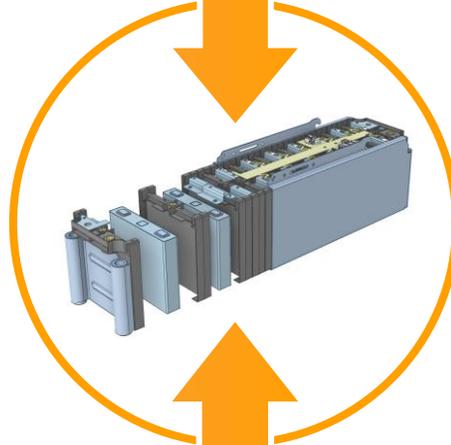


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PROVENTIA

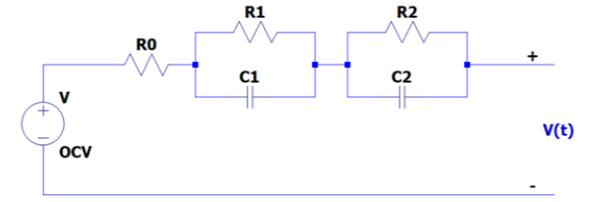
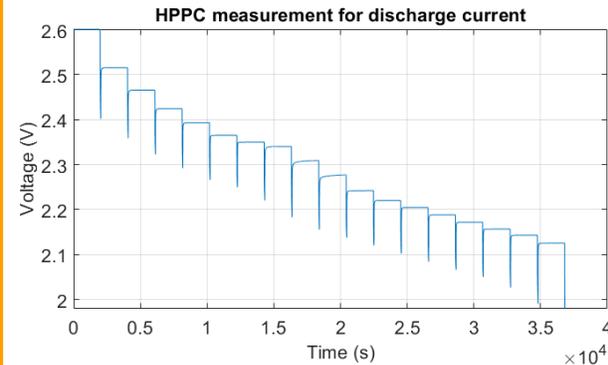
CELL DATA

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BATTERY SIMULATION MODELS

Equivalent Circuit Model



- Each circuit parameter can be defined as a function of SOC, temperature, and current
- Hybrid pulse power characterization (HPPC) data is used to define the parameters

INITIAL BATTERY SIZING

CUSTOMER DATA

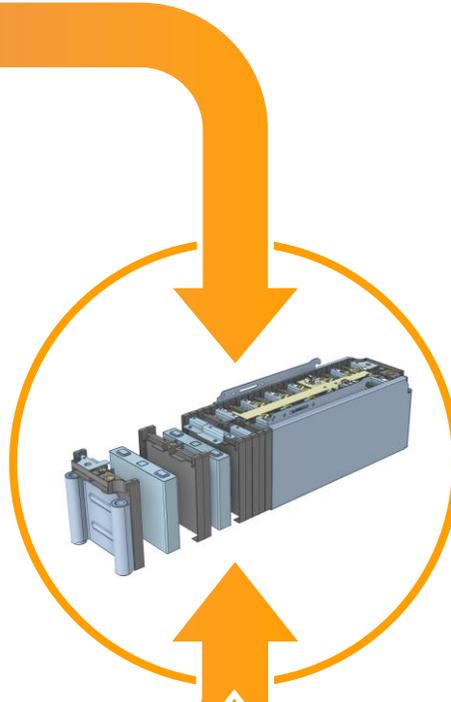
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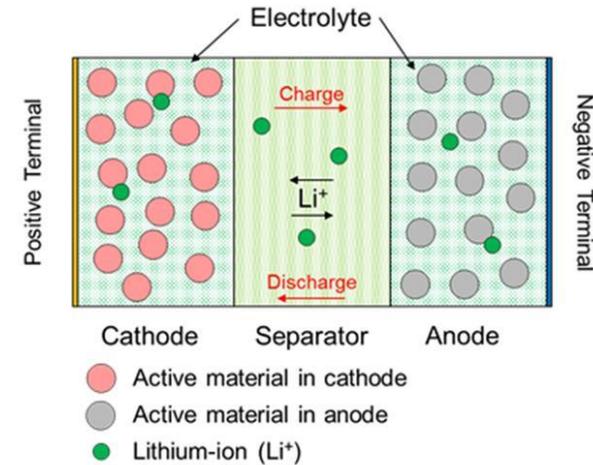
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BATTERY SIMULATION MODELS

Electrochemical model



Source: Gamma Technologies. GT-AutoLion User Manual; Gamma Technologies

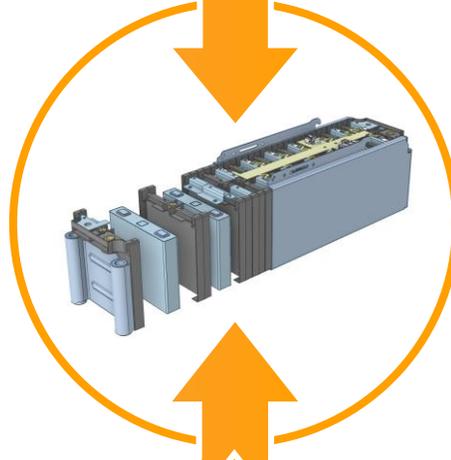
- Physical representation of the electrochemical reaction processes inside a lithium-ion battery
- Complex model that requires in-depth knowledge of battery chemistry to build

INITIAL BATTERY SIZING

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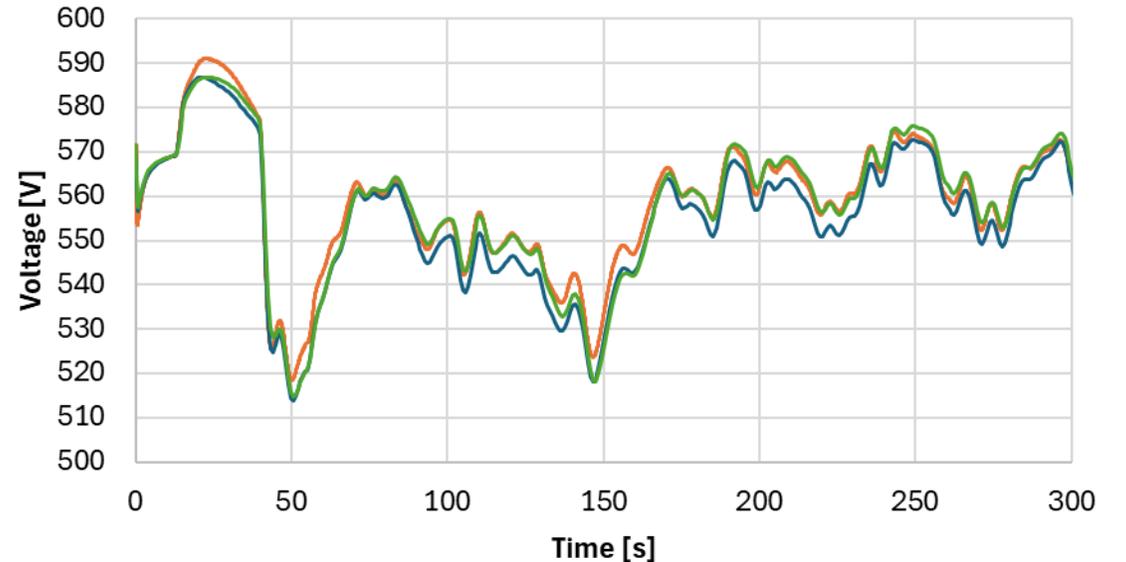
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BATTERY SIMULATION MODELS

552 V system voltage comparison



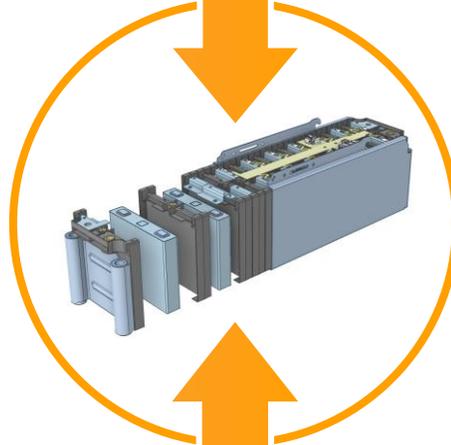
- In initial tests the average error between the models was approximately 1.5 %

INITIAL BATTERY SIZING

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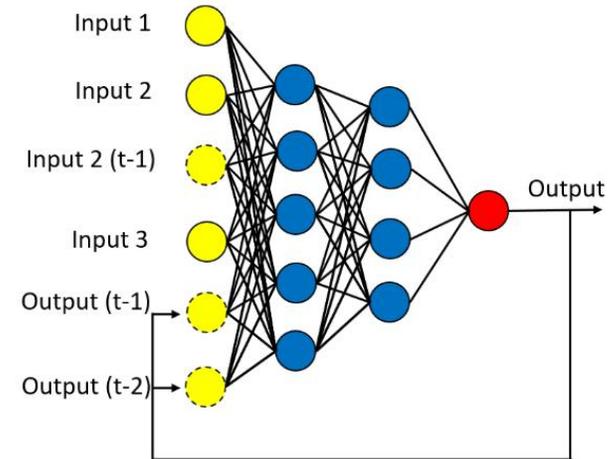
CELL DATA

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BATTERY SIMULATION MODELS

Machine Learning model



Source: Gamma Technologies. GT-Post User Manual; Gamma Technologies

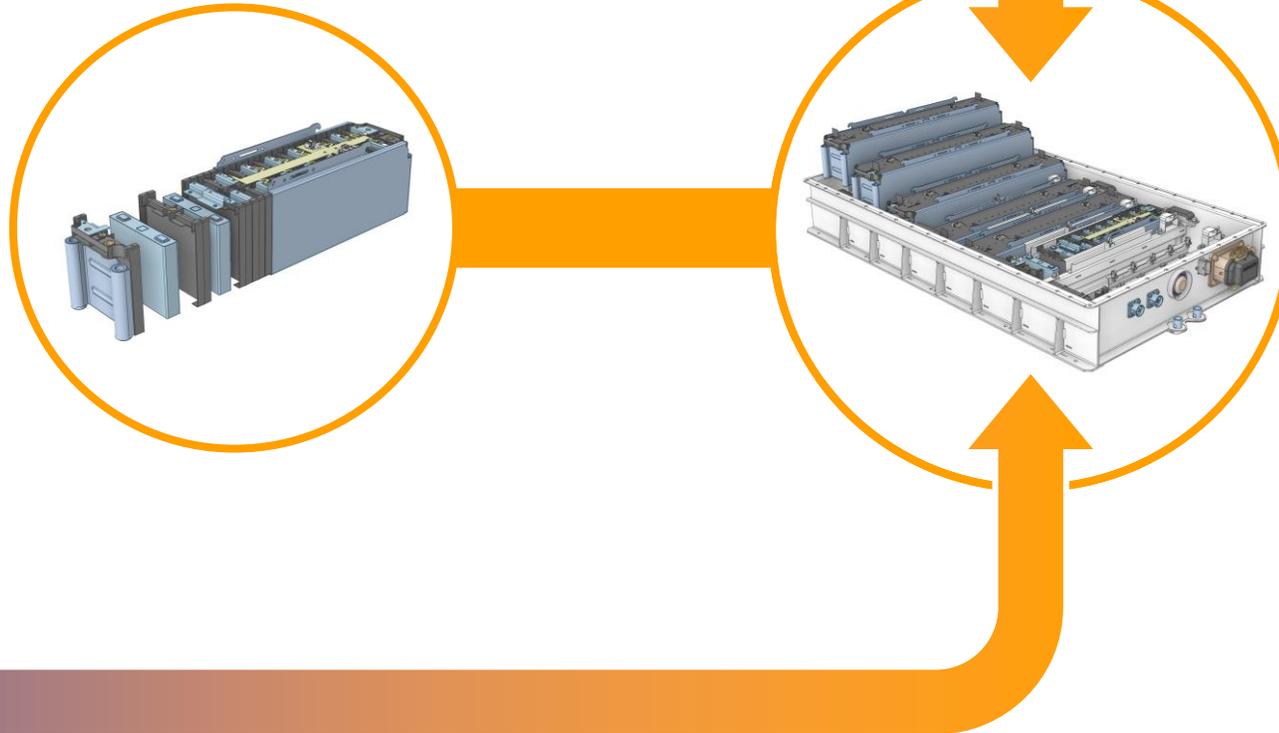
- Based on Nonlinear autoregressive model with exogenous inputs (NARX)
- Trained with sufficiently large amount of input data
- Can be trained with simulated and measured data

BATTERY PACK DESIGN

CUSTOMER DATA

- Battery environmental conditions
- Required vibration and shock standards
- Space claim

- System simulation model
- Detailed thermal simulation
- Initial structural simulation
- Vibration data from a similar NRMM



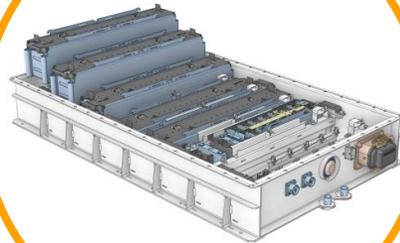
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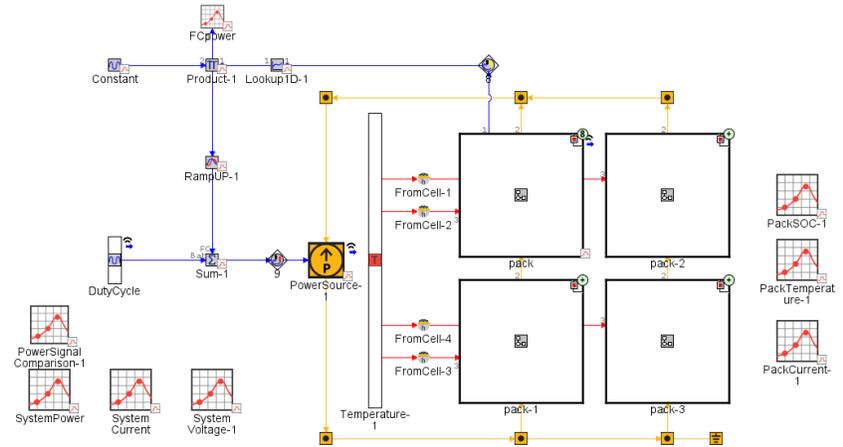


- System simulation model
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PROVENTIA



SYSTEM SIMULATION



- System electrical performance is verified
- Battery ageing simulation
- Battery rejected heat during load

Battery system model can be provided for customer system simulation

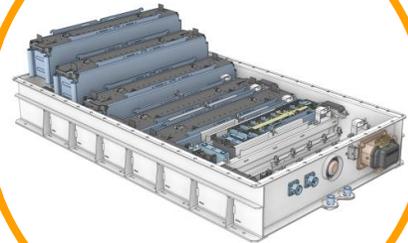
- Usually in FMU-format
- Encrypted native files can be also used

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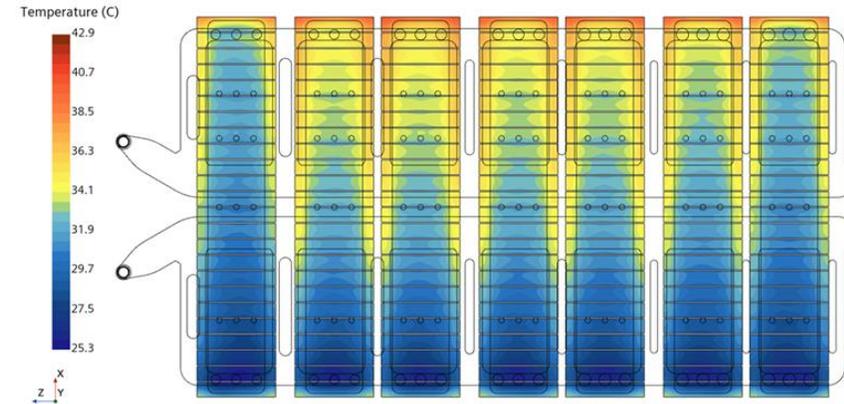
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THERMAL SIMULATION



- Coldplate coolant channel layout
- Coolant channel flow is balanced
- Battery heat load is imported from system simulation
- Thermal performance of the cooling system is simulated either in steady-state or transient
- Goal in evenly distributed temperature with efficient cooling
- Heat transfer values to system simulation

PROVENTIA



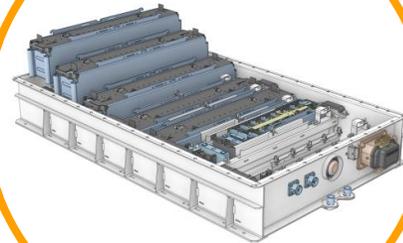
BATTERY PACK DESIGN

STRUCTURAL SIMULATION

CUSTOMER DATA

- Battery environmental conditions
- Required vibration and shock standards
- Space claim

- System simulation model
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- Vibration data from a similar NRMM



- No comprehensive non-road mobile machinery standard
- Combination of different existing standards
- Several applicable standards for heavy duty battery systems
 - Ground vehicle installations (IEC 60271...)
 - Road vehicles (ISO 16750-3...)
 - Automotive on-road (ECE R100...)
 - Maritime battery standards (DNV...)
 - Battery transport (UN 38.3...)
- Standards do not remove the need to consider application specific validation

PROVENTIA

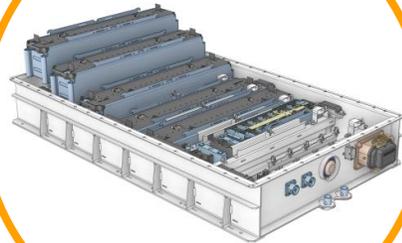


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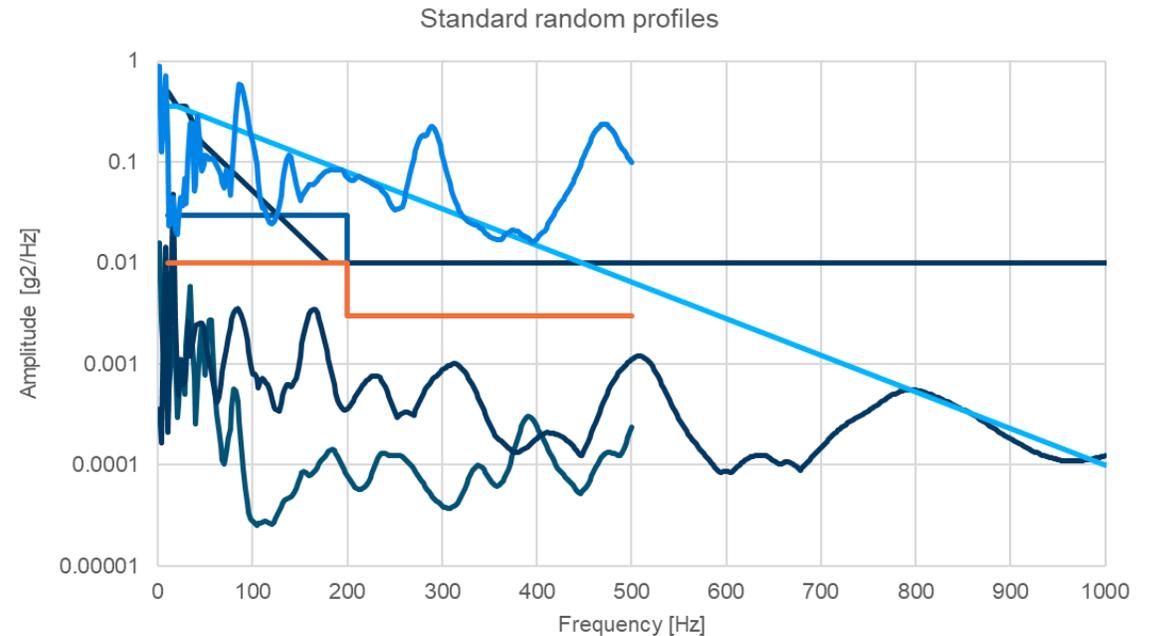
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STRUCTURAL SIMULATION



- IEC 60271-3-5 PSD 5M3
- Agriculture application
- ISO 16750-3:2023; Commercial, electric vehicle
- Forestry application
- ISO 16750-3 Commercial vehicle, body, PSD
- Mining application
- IEC 60271-3-5 PSD 5M2

PROVENTIA

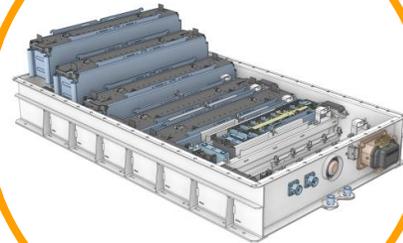


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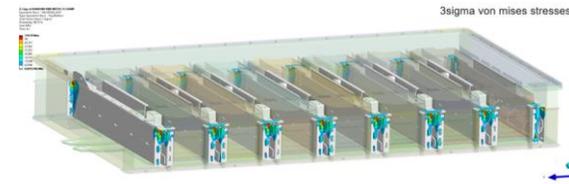
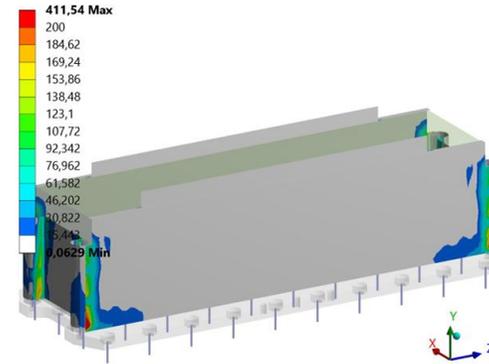
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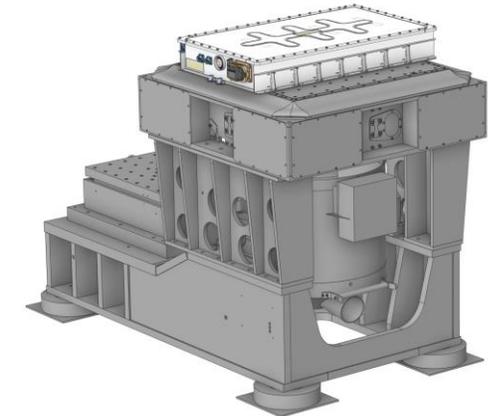


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PHYSICAL VALIDATION



- System is designed to withstand mechanical loads and the design is verified with physical testing

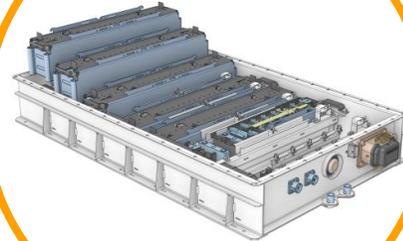


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PROVENTIA

LABORATORY TESTING



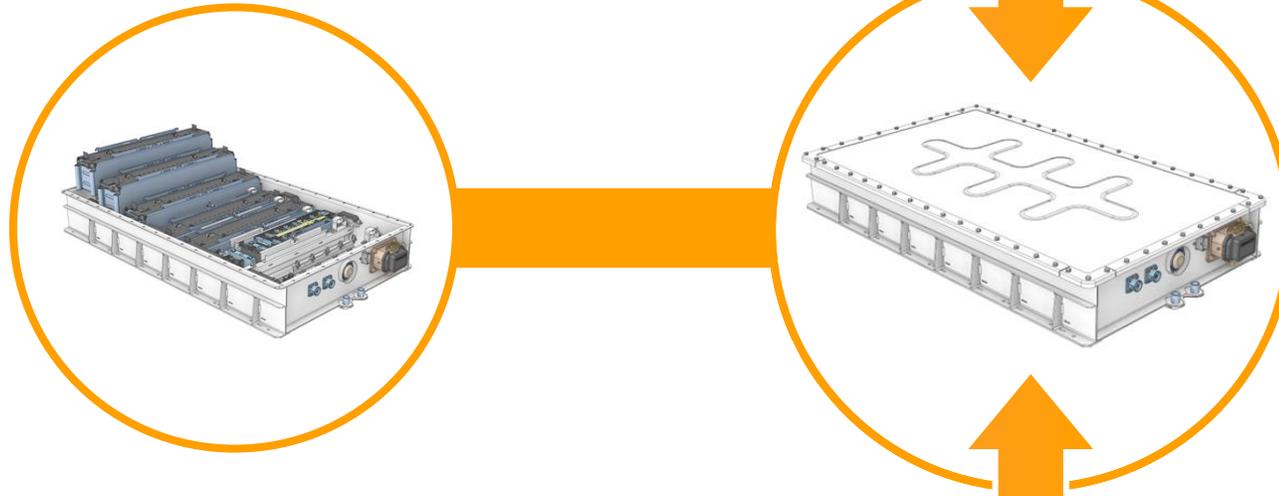
- System electrical performance is tested
- Customer load cycles are specific test required by the customer are done
- Battery pack thermal management is tested
- Simulation results are validated
- Possible to test a hybrid system

FINAL PRODUCT

CUSTOMER DATA

- Operational data
- Experiences with the developed system

- Final system simulation model
- Telemetry data analysis
- Technical support



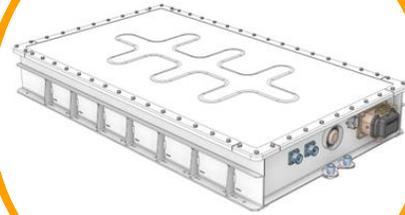
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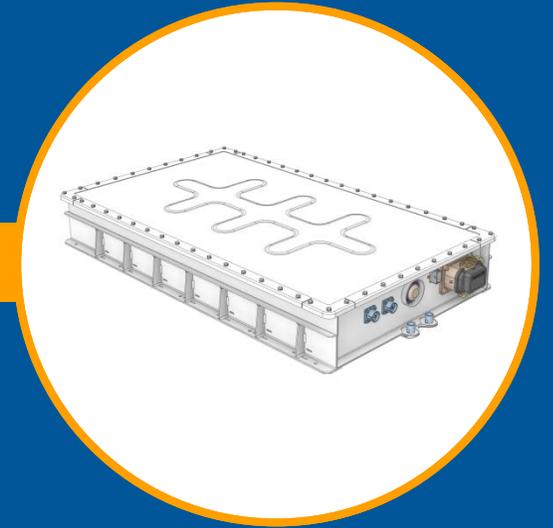
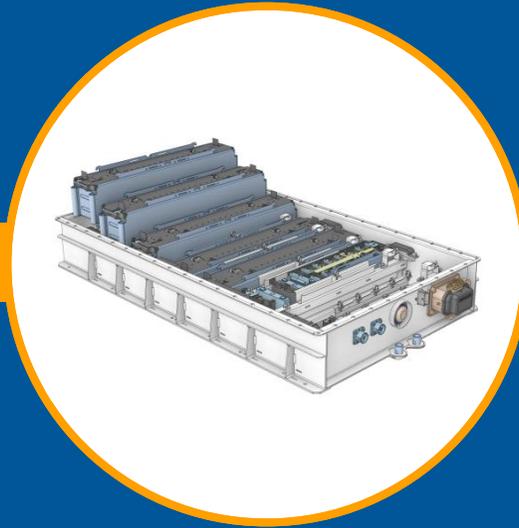
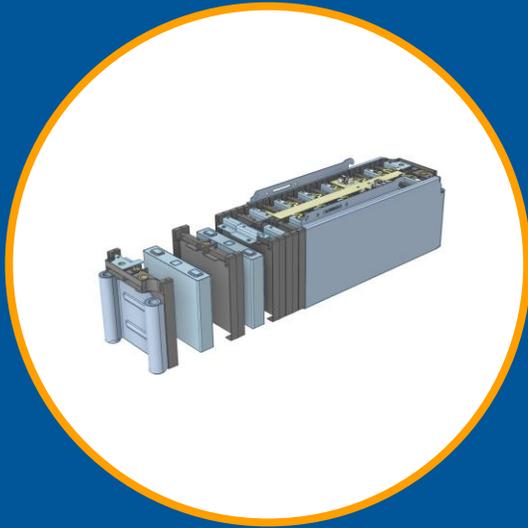
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TELEMETRY



- Batteries can be monitored in field conditions by logging data from it
- Allows use of external models and algorithms to evaluate battery conditions e.g., state of health (SOH) calculation

BENEFITS OF DATA DRIVEN APPROACH



1. **Faster development cycles:** Simulations accelerate the battery design process.
2. **Improved performance with optimal size:** Data-driven designs result in batteries that are better suited for specific uses, offering improved efficiency and capacity.
3. **Enhanced safety:** Minimizes aging and environmental risks.
4. **Reduced costs:** Efficient development and optimized designs cut costs.

THANK YOU FOR YOUR INTEREST

Sauli Halonen

Senior R&D Engineer

sauli.halonen@proventia.com

www.proventia.com

