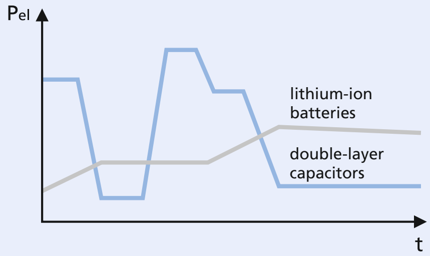
FRAUNHOFER INSTITUTE FOR TRANSPORTATION AND INFRASTRUCTURE SYSTEMS IVI



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DUAL ENERGY STORAGE SYSTEMS

Motivation

While traction energy storage systems of modern hybrid cars are being charged and discharged with moderate continuous power and charge power pulses respectively, the requirements for traction applications in commercial vehicles with regard to

- power availability
- energy density
- failure safety
- charging cycle stability

are much higher. High dynamic power profiles, as they are found in the area of public transport, require high-performance dual energy storage systems. These consist of an energy storage part with high power density to cover acceleration and recuperation processes and an energy storage part with high energy density to realize all-electric, and thus local emission-free driving. While electrochemical double-layer capacitors have advantageous properties in terms of power density, high energy densities are achievable with lithium-ion battery cells.

The efficient operation of dual energy storage systems require high-performance management and control algorithms. One of the main objectives of Fraunhofer IVI is the development of such algorithms comprising battery models. These models are based on the analysis of single energy storage cells and describe the cell's electrical and thermal behavior accurately.

To enhance efficiency and to increase power availability on-line prediction algorithms are used to control the distribution of the electrical power to the high-power storage and the high-energy storage. Furthermore, precise models and failure prediction algorithms allow for an increased reliability of the storage system. Comprising traffic data, such as current position, previous acceleration profile, and driver command in the energy management - which are particularly available in public transport - allow for significant fuel savings.

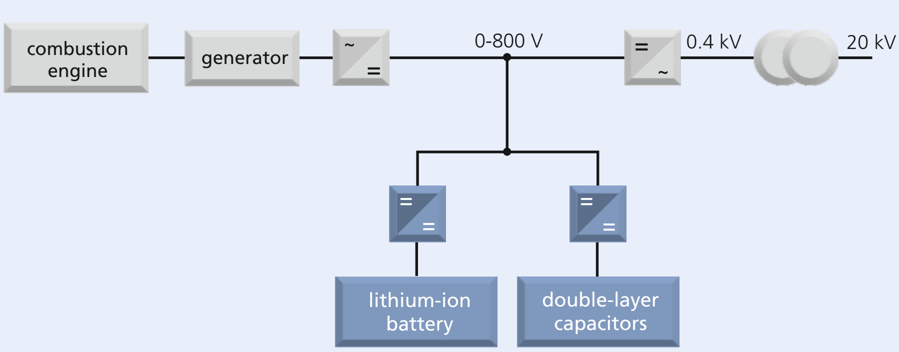
1 *dual energy storage systems – power control*
2 *lithium-ion cell*
3 *electrochemical double-layer capacitor module*

Fraunhofer Institute for Transportation and Infrastructure Systems IVI
Director:
Prof. Dr. Matthias Klingner

Zeunerstrasse 38
01069 Dresden
Germany

Contact
Dr. Ralf Bartholomäus
Phone +49 351 4640-815
ralf.bartholomaeus@ivi.fraunhofer.de

www.ivi.fraunhofer.de



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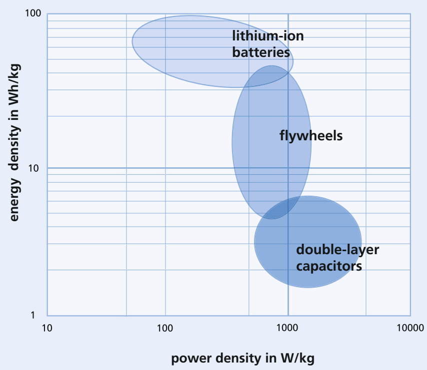

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Housings for electrochemical double-layer capacitors and lithium-ion cells, which fix the individual cells safely and enable efficient cooling, are developed at the Fraunhofer IVI as well. Using innovative sensor technologies, reliability and maintenance are improved significantly.

Key aspects

- characterization of lithium-ion cells and electrochemical double-layer capacitors by test plan generation, data acquisition, and evaluation,
- development and parameterization of electrical and thermal simulation models,
- design and analysis of customized battery systems including DC-DC converters, cooling system, wiring, etc.,
- dimensioning of the high-power and the high-energy part for dual energy storage systems,
- simulation and optimization of individual components as well as the entire system,
- sensor concept and data acquisition for dual energy storage systems,
- development of battery management systems to monitor state of charge, state of health, and cell temperatures, and for diagnosis of energy storage modules
- optimal energy management by model predictive control (MPC) of power flux and cooling, computation of feasible load profiles.

Tools and test facilities

- simulation tools (FEM/CFD, block-based simulation)
- test facilities for data acquisition and system test

1. test bench for individual cells
   - 0 V to 5 V / -500 A to +250 A
   - climate chamber for cell conditioning
   - high-performance and high-precision data acquisition
   - test of cooling systems

2. test bench for small modules
   - 0 V to 15 V / -400 A to +400 A
   - climate chamber for module conditioning
   - modular power electronics with CAN interface

3. test facility for traction energy storage systems
   - 0 to 800 V / -1000 to +1000 A
   - max. 250 kW continuous power (300 kW peak power)
   - for systems up to 1000 kg
   - temperature range from 0 to 60 °C
   - testing with vehicle power electronics (DC-DC converters)
   - automated long time tests with CAN interface
   - real-time data acquisition with powerful and robust measurement hardware

Expertise

- modeling thermal processes and coolant flow in energy storage modules, simulating heat transfer and CFD with Ansys® and Comsol®
- optimal and predictive control of energy storage systems and energy management of hybrid drive trains
- microcontroller based data acquisition and processing
- in-house developed, highly flexible test infrastructure (modular power electronics, precise measurement, temperature control)

Key benefits

- design of battery systems based on customers specification including peripheral components such as DC-DC converter or cooling system
- development of advanced battery management software for your battery system in order to increase reliability, efficiency and power availability, and thus to decrease costs, weight and installation space
- realization of comprehensive measurements, analysis and simulation of your battery system and individual energy storage cells
- development of optimized design rules in terms of module geometry, load requirements, and cooling system

4 *block diagram of the Fraunhofer IVI battery test facility*

5 *Ragone plot representation of power and energy density*