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INTELLIGENT ENERGY SYSTEMS

ELECTRICAL AND CHEMICAL ENERGY STORAGE, CONVERSION, AND TRANSMISSION FROM MILLIWATTS TO GIGAWATTS

The department "Intelligent Energy Systems" at Fraunhofer IISB develops advanced technologies and electronic modules for the digitalization of energy storage solutions and power conversion systems for mobile and stationary applications, thus building our "Cognitive Power Electronics" ecosystem that covers the entire power range from a few milliwatts up to several gigawatts. We integrate innovative data analytic technologies in our solutions, enabling smart diagnostic and monitoring functions to our cutting-edge electrical power converters, to our high-performance battery and hydrogen systems, including our disruptive open-source battery and fuel-cell management system foxBMS®. Our research and development efforts focus on power and control electronic hardware, as well as on software algorithms and data processing technologies – making intensive use of artificial intelligence – applied to anomaly detection in energy systems and energy management solutions targeting the energy and transportation domains.

1 *Condition monitoring of an electric drive by CPE4.0, with estimation of the most probable cause of failure. © Kurt Fuchs / Fraunhofer IISB*

2 *Test stand for the investigation of hydrogen-based fuel cell systems. © Kurt Fuchs / Fraunhofer IISB*

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FRAUNHOFER INSTITUTE FOR INTEGRATED SYSTEMS AND DEVICE TECHNOLOGY IISB

ENABLING THE ALL ELECTRIC SOCIETY:

INTELLIGENT ENERGY SYSTEMS

SMART ENERGY FROM MILLIWATTS TO GIGAWATTS

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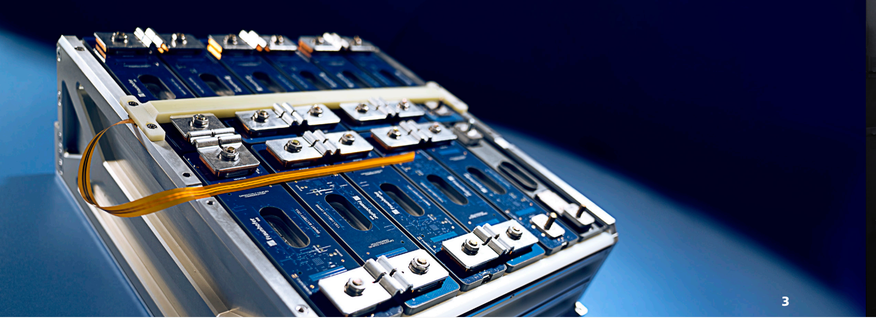

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ACTIVITIES AND EXPERTISE

Integration of Complex Hydrogen Systems and Operating Strategies

Special about our expert team is the combination of competencies in hydrogen system integration, components modeling and simulation, energy system automation and integration, AI-based intelligent control algorithms and operation strategies.

Our unique real-world laboratory for intelligent decentral energy systems supplies the environment for electrical, thermal, and chemical energy storages, thus mastering the complete energy chain. Outstanding is the integration of a liquid organic hydrogen carrier (LOHC) based system into the DC microgrid of Fraunhofer IISB combined with battery systems, power electronic converters, and the overall operating strategies. The system enables the storage of hydrogen under ambient conditions within a liquid, so neither compression nor cooling is needed for the storage of hydrogen itself. The sustainable energy generation, the production of hydrogen by electrolysis, the hydrogenation and dehydrogenation, and finally the electrical power generation by fuel cells is demonstrated and analyzed. The complete system is digitally mapped and used for the development of intelligent operating strategies, models of the components as well as advanced simulations.

Full Service for DC Microgrid Development and Implementation

From the customer idea to the industrial application: We develop the perfectly optimized and standard conform solution for you. At first, the individual implementation of a complete DC microgrid includes grid planning, network and component design, as well as numerical simulation. For the set-up of your system, we offer full-custom power electronics components, protection devices, electrical safety, diagnostics, and stability analyses.

Our DC experts hold a leading position in the national and international standardization processes concerning low voltage DC industry applications (IEC PT 63317). As a current example, in the project “DC-Industrie 2”, together with 40 partners, we developed a comprehensive system concept for DC-based industry applications. A core contribution to this project is our isolated DC/DC converter and the development of the characteristic curve-based control for the voltage stabilization of a factory wide DC-Microgrid in different production facilities.

For more information about intelligent energy systems visit: https://www.energy-seeds.org

3 *Smart Lithium-ion battery cells with contactless data communication interface. © Anja Grabinger / Fraunhofer IISB*

4 *Dynamic real-time analysis of power electronic components using novel measuring technology based on the injection of artificially generated noise signals, consisting of test network, measurement device, load and DC source. © Kurt Fuchs / Fraunhofer IISB*

5 *SVC PLUS Modular Multilever Converter” © Siemens AG*

Certification-ready Open-source Battery Management System: foxBMS® 2

With foxBMS 2 (foxbms.org) Fraunhofer IISB now delivers the second generation of its open-source battery management system (BMS). foxBMS 2 is an advanced research and development platform offering a high level of functional safety and advanced edge-cloud possibilities, enabling fast prototyping of complex battery and fuel-cell systems. It includes all necessary hardware and software for nearly any kind of mobile and stationary application that uses modern rechargeable electrochemical energy storage systems, like lithium-ion, lithium-sulfur, lithium-metal, aluminum-ion or even redox-flow batteries and fuel cells.

Cognitive Power Electronics 4.0

With "Cognitive Power Electronics 4.0" (CPE4.0) we combine our competencies in the field of power electronics with data analytics and artificial intelligence applied to complex energy systems. The CPE4.0 technology enables innovative applications of smart power electronics, from data analysis and health monitoring at device level up to anomaly detection and predictive maintenance in interaction with the cloud. Examples of developments are inverter-based health monitoring functions for electric drives without additional sensors, power converter-based impedance spectroscopy and stability optimization in DC grids.

Design of Components and Submodules for Modular Multi-Level Converters

The state-of-the-art approach to transport electrical energy and reach a high grid quality in medium and high-voltage power distribution are based on modular multi-level converters (MMC). Scalable in voltage and power, they use stacked submodules, which are developed by Fraunhofer IISB in various voltage, current, and topology ranges for different customers worldwide. Our turn-key designs include all required disciplines, from concept definition, mechanical, thermal and electrical design, plus redundancy and safe failure mode considerations far beyond the prototype stage, also PCB development for special requirements. After the design phase, the design verification is processed in other IISB departments to guarantee an objective testing for our customers.

foxBMS® free.open.flexible

For more information about foxBMS visit: https://foxbms.org

For more interesting projects, visit our website: https://www.iisb.fraunhofer.de/ies-projects

ACTIVITIES OF THE RESEARCH GROUPS

The group “**Battery Systems**” develops innovative solutions for rechargeable electrical energy storage systems, e.g., lithium-ion or redox-flow batteries for mobile and stationary applications. The activities range from the development of battery management systems with the foxBMS platform, algorithms for battery state estimations and predictions, up to the design of full-custom battery systems for high-performance applications like racing cars, submarine exploration robots, airships, or electric gliders.

The group “**DC Grids**” focuses on innovative solutions for local DC Grids and practical solution for a fast integration into our classic AC Grid. Their work ranges from applied research, e.g., on safety and stability issues of the voltage and power converter control, through concept studies, up to the development of innovative grid components, such as customized DC/DC converters, electronic DC circuit breakers, DC plugs, and overvoltage protection devices. The group is also represented on boards such as VDE/DKE, IEC, eMerge Alliance, and IEEE Smart Grid.

The group “**Industrial Power Electronics**” is solving critical power electronic challenges in the field of multi-level converters in all voltage ranges. Whether development support for components or submodules, problem analysis for running facilities and equipment, the list of strengths in the field of troubleshooting of this group is large: longstanding industrial application experience, fast response time, and familiarity with industrial processes.

The group “**Energy Technologies**” develops and optimizes intelligent and decentralized energy systems covering different energy sectors. A focus is on the development of hydrogen systems consisting of fuel cells, electrolyzers, and hydrogen storages in the energy and transportation domains. The emphasis is on system integration of complex components. These include energy storage systems, i.e., electrical, thermal, hydrogen, and chemical as well as components like fuel cell, electrolyser, battery and power electronic converters. The interaction of these components is optimized by intelligent operational strategies. These use forecasts and algorithms to improve the CO2 footprint, the energy efficiency, the sector coupling, and peak load reduction.

The group “**Data Analytics**” develops innovative AI-based solutions to get the most out of data generated in the context of Cognitive Power Electronics 4.0 and Industry 4.0. The group takes an application-oriented approach that includes system analysis, conception, data collection, filtering, clustering, and finally the development and implementation of intelligent algorithms in embedded systems or in industrial processes.