ISES

Institute for Sustainable Energy Systems

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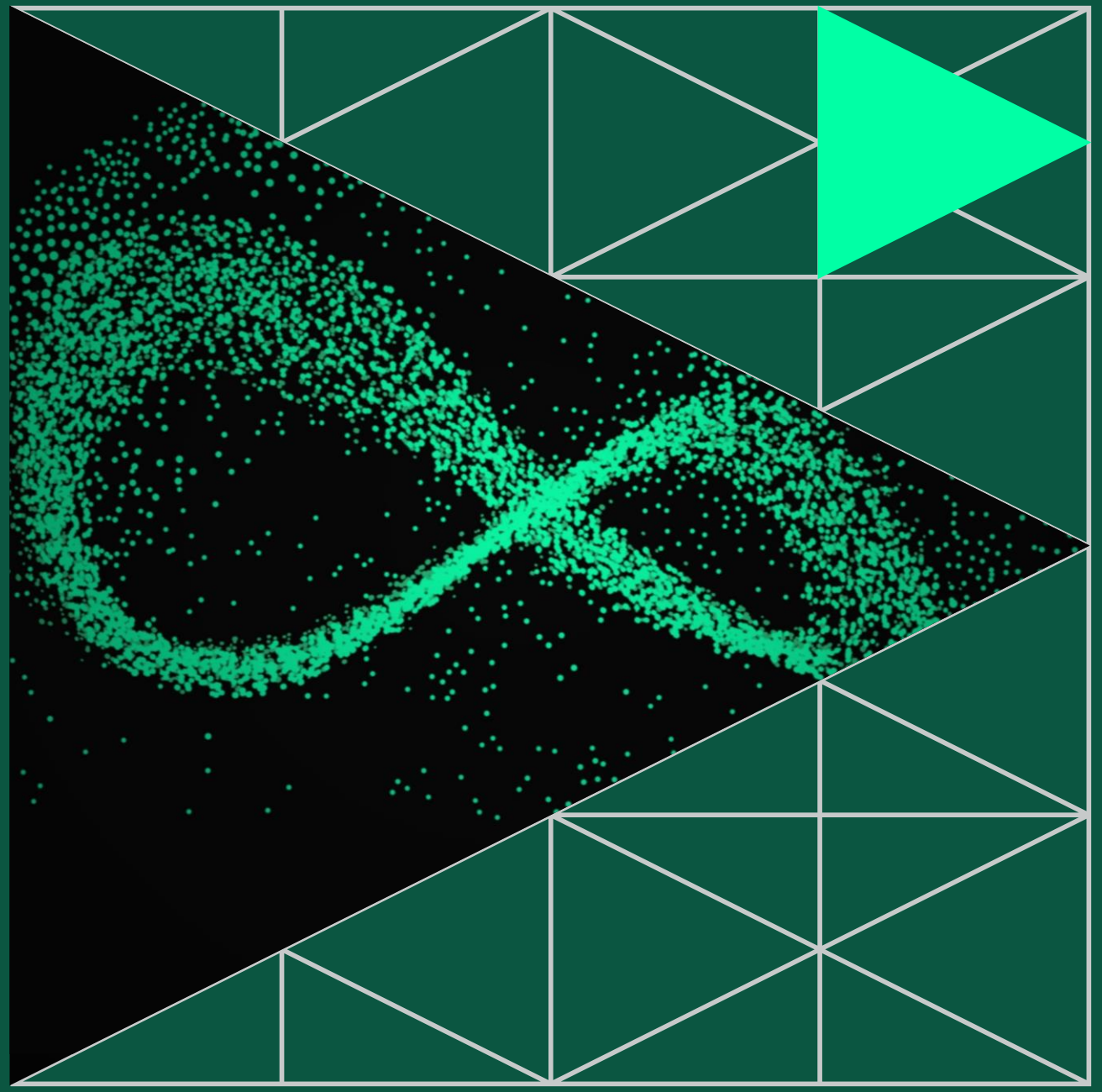
Version 2024.05.22



HM

Facts & Figures

Institute Founding

01.10.2019

~ 14 Mil. Euro

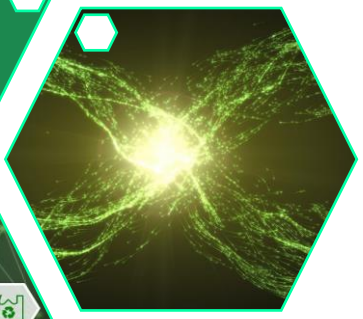
3rd party funding

81

Cooperation partners

75%

Funding approval rate



44

Staff members

301

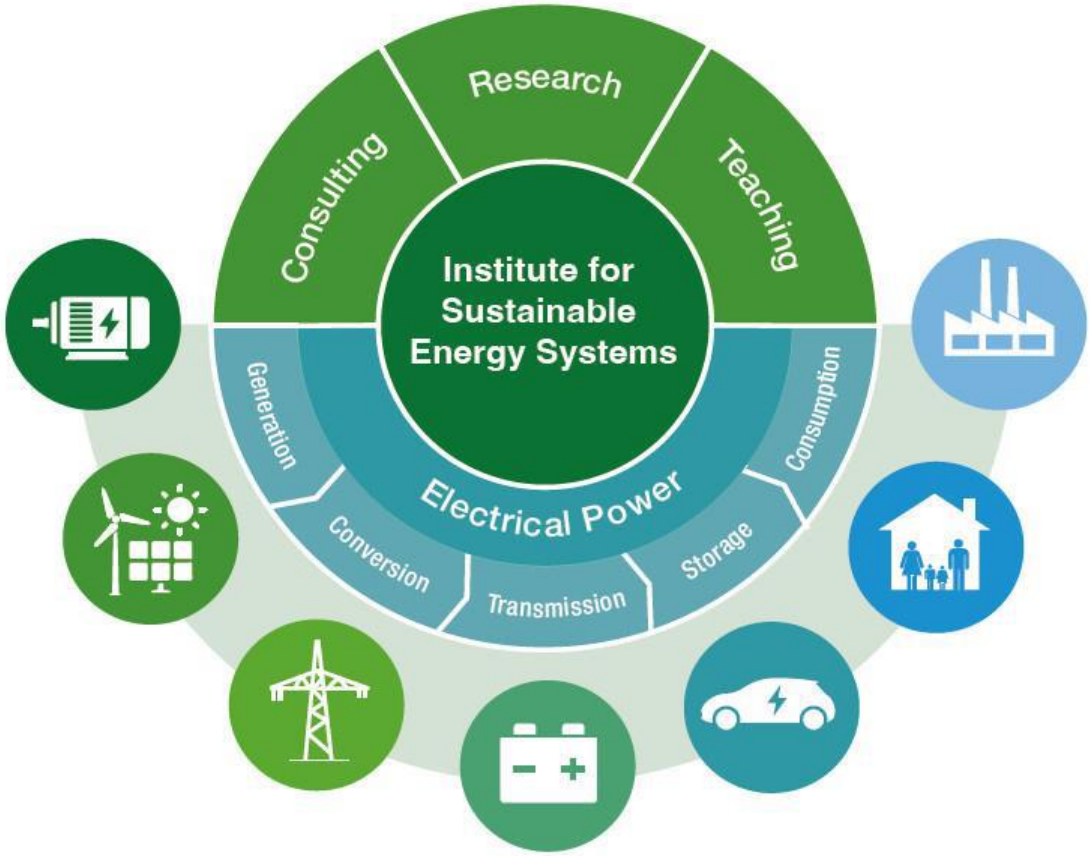
Bachelor and master theses supervised

202

Publications

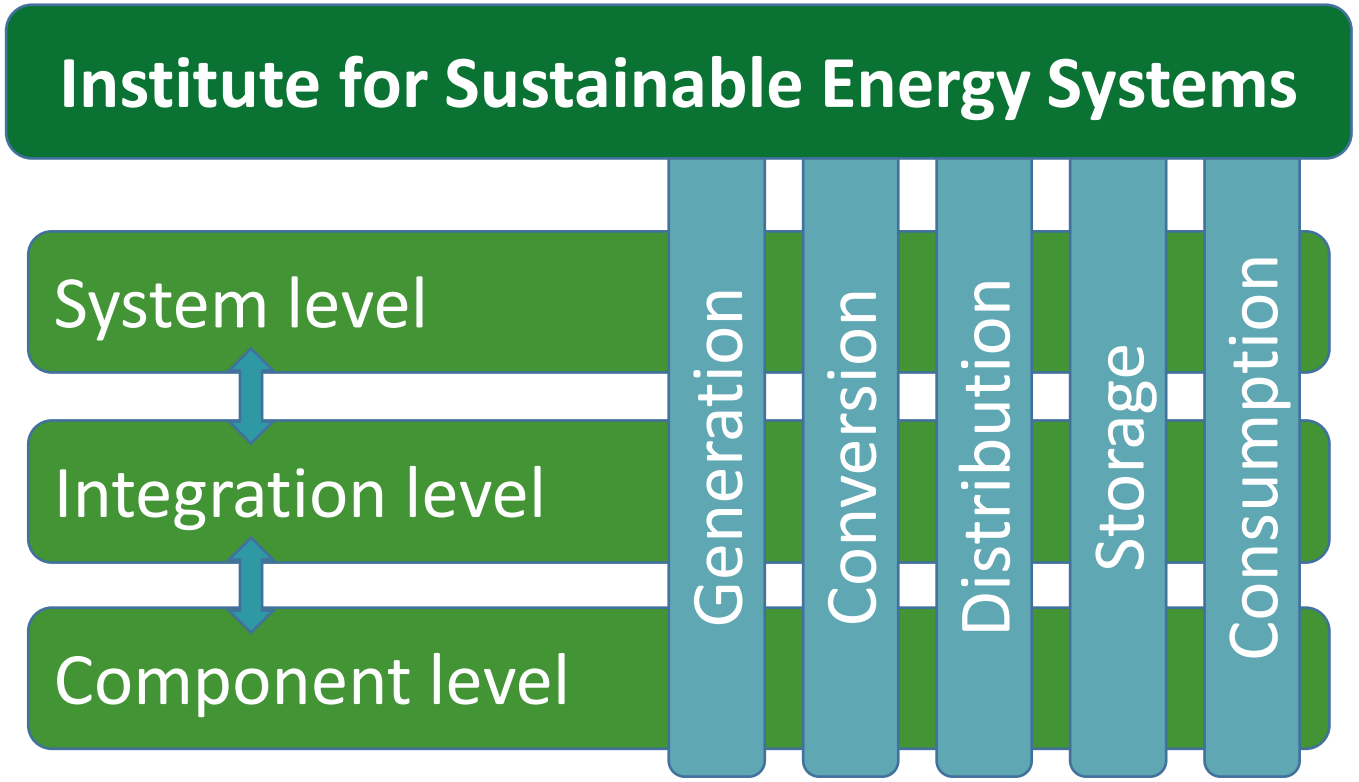
HM ISES Institute for Sustainable Energy Systems

Our Mission



- With our research, consulting and teaching activities, we make a considerable contribution to a more efficient, sustainable and resource-conserving approach to energy supply and use
- Meeting global climate and energy targets is a major goal we aim to contribute to
- Sustainability is our focus area

Our Competence



- We conduct research on electrical energy conversion, distribution and storage
- We research energy systems in their entirety from the component to the system and across all stages of the value chain, from generation to consumption

Our Team

Leading team and research areas

- Florentina Alecu
  Managing Director / Research Coordinator

- Oliver Bohlen
  „Electrical Energy Storage“

- Christoph Hackl
  „Mechatronic and Renewable Energy Systems“

- Herbert Palm
  „Systems Engineering“

- Simon Schramm
  „Solar Technology and Electrical Power Systems“

- Stephanie Uhrig
  „Electrical Power Engineering“

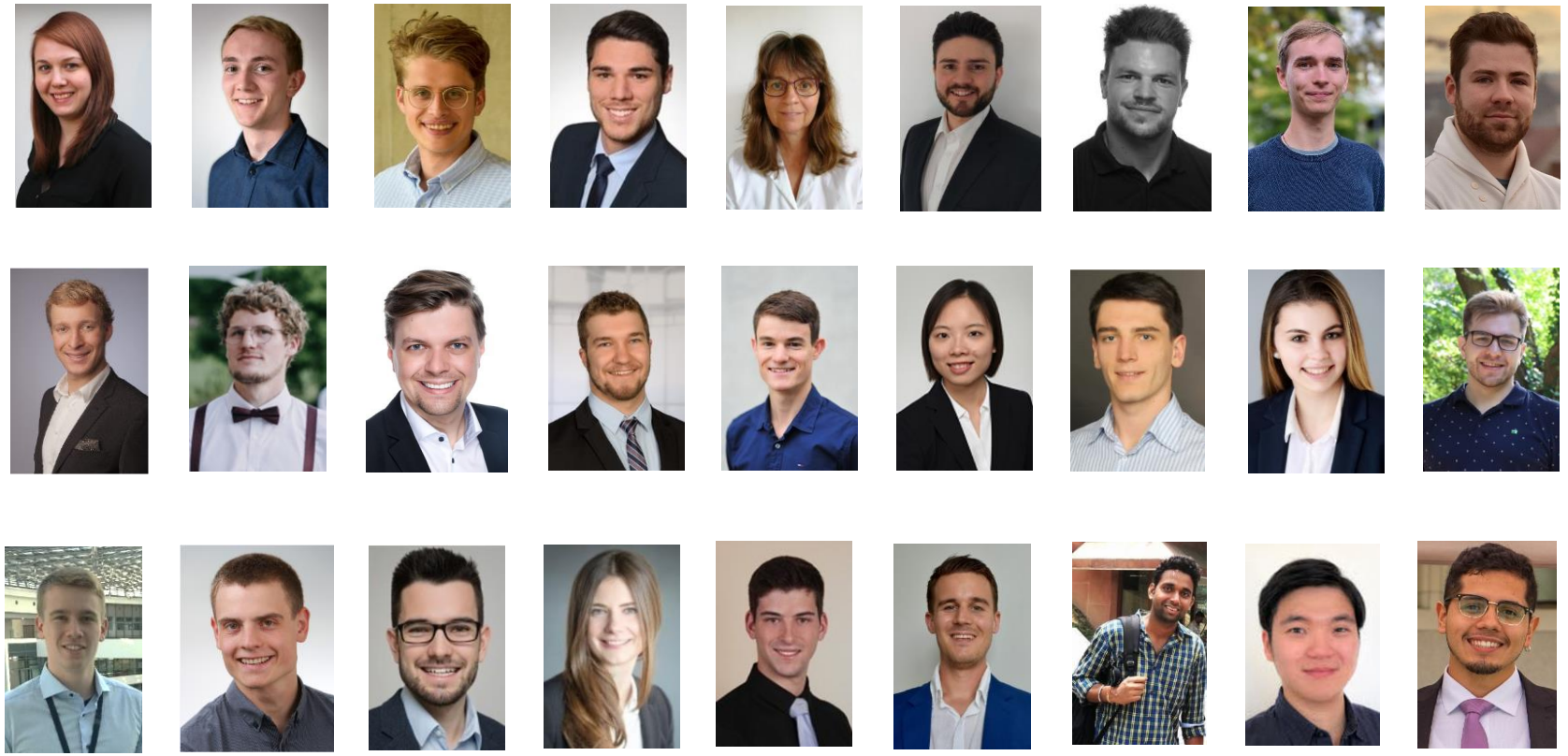
- Marek Galek
  „Electrical Energy Conversion and Power Electronics“

- Georg Kerber
  „Electrical Power Supply Networks“

- Axel Busboom
  Associate Professor Research Area „Industrial Digitalisation“

Our Team

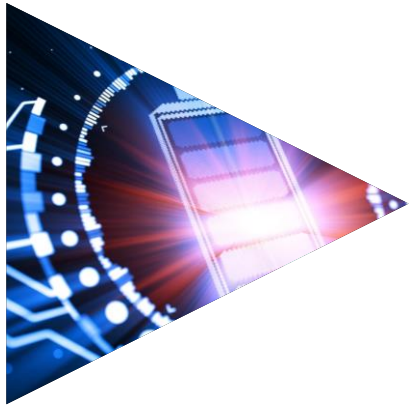
Our research scientists



Our Research Areas

@Riccardo Annandale(unsplash)

Area of Expertise



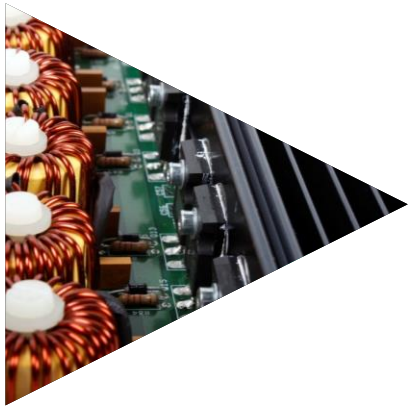
Electrical Energy Storage

Mechatronic and Renewable Energy Systems

Systems Engineering

Solar Technology and Electrical Power Systems

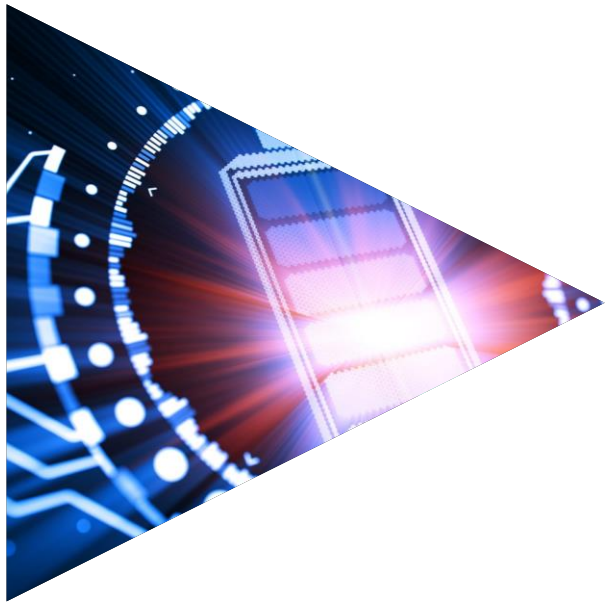
Electrical Power Engineering



Electrical Energy Conversion and Power Electronics

Electrical Power Supply Networks

Electrical Energy Storage



- The research group “Electrical energy storage” focuses on systems for storing electrical energy - primarily batteries - and the respective applications such as electric vehicles, home storage systems, e-bikes, etc.

- The thematic focus is on battery system technology, i.e. everything that goes with it to turn battery cells into a functioning overall system. This includes:

  - **Battery characterization**, such as pulse and capacity tests, impedance spectroscopy, thermal analysis
  - **Modelling and simulation** of electrical, thermal and ageing behaviour using tools such as Modelica, Python and Matlab / Simulink
  - **Battery management** systems and algorithms for state of charge and state of health monitoring, energy management and optimal power flow in storage systems
  - **Battery electronics**, prototyping for battery systems and BMS electronics for e-bikes and other applications

Mechatronic and Renewable Energy Systems

- The research group „Mechatronic and Renewable Energy Systems“ focuses on: system modelling, identification, fault detection, condition monitoring and control of mechatronic and renewable energy systems
- Particular interests are efficiency, fault tolerance, intelligence, robustness and reliability oft he considered, self-learning systems and components
- The interdisciplinary expertise of the group merges the engineering disciplines electrical drives, power electronics & mechatronics and the mathematical disciplines control and systems theory
- Recent research projects deal with
  - the modelling and analyses of the future power grid as a four-wire three-phase system (including harmonics and arbitrary faults)
  - the design, modelling and control of the electrical components of electric vehicles, biogas plants, airborne wind energy systems, geothermal power plants, large-scale and small-scale wind turbine systems and wave converters
- More details are available on https://lmres.ee.hm.edu/.

Systems Engineering

- The research group „Systems Engineering“ focuses on methods and tools for modelling, simulation and multicriterial optimization of complex systems
- Particular interest focuses on development of effective and efficient search algorithms to identify non-dominated („Pareto-optimal“) system layouts for a high (larger than ten) number of design degrees-of-freedom
- The interdisciplinary expertise of the group merges technical engineering disciplines such as power engineering, mechanical engineering and computer science with methodological (INCOSE) systems engineering competencies
- Recent research projects deal with
  - Pareto-optimal layout of sector-coupled, decentralized, sustainable energy systems for multi-use-case scenarios
  - Pareto-optimal power-flow operational strategies for stationary battery-energy storage systems (BEESs)
  - Hyper-Space-Exploration for highly effective and efficient layout of neural network hyperparameters

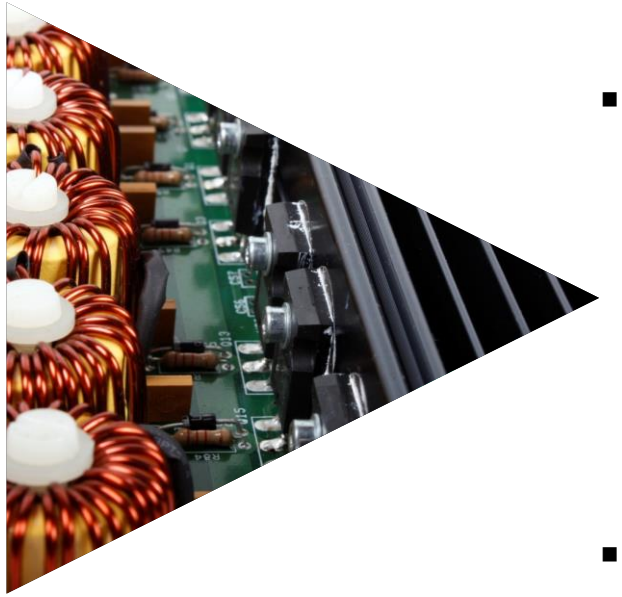
Solar Technology and Electrical Power Systems

- The research group „Solar Technology and Electrical Power Systems“ focuses on topics relevant for the “Energiewende”:
  - **Solar generation**, e.g. accelerated life time test of components, e.g. of vehicle integrated PV, low cost high performance monitoring, system design and operation
  - **Power electronics** required to connect AC to DC or DC to DC-Systems, e.g. high performance AC/DC and DC/DC-converter with galvanic insulation – design, control, test, operation (e.g. with predictive control based on analytic equations)
  - **Energy efficiency**, e.g. data driven analysis of energy consumption in small up to complex building systems
  - **Energy system planning**, e.g. system planning tool energy systems with high penetration renewables, including sector coupling, and its control
- All topics include theory and practice, applied research, including e.g. modelling, automated data analysis, rapid prototyping, and test, thus theory and validation

Electrical Power Engineering

- Diagnostics and condition assessment of power system equipment:
  - Equipment in our power grid is subjected to loads and stresses, resulting in ageing or occurring defects
  - Using diagnostic measurements, it is possible to assess the condition of the equipment, i.e. to estimate the degree of aging and to identify possible causes of errors at an early stage
- Controllable loads in the distribution network:
  - Smart Grids of tomorrow are achievable only by higher efficiency and optimized utilization of existing structures
  - A promising approach uses controllable loads (time-flexible consumers) in the distribution network
  - Energy consumption is shifted to times with energy surplus

Electrical Energy Conversion and Power Electronics



- The research area Energy Conversion and Power Electronics deals with the development of electrical energy converters, as well as with the resulting effects

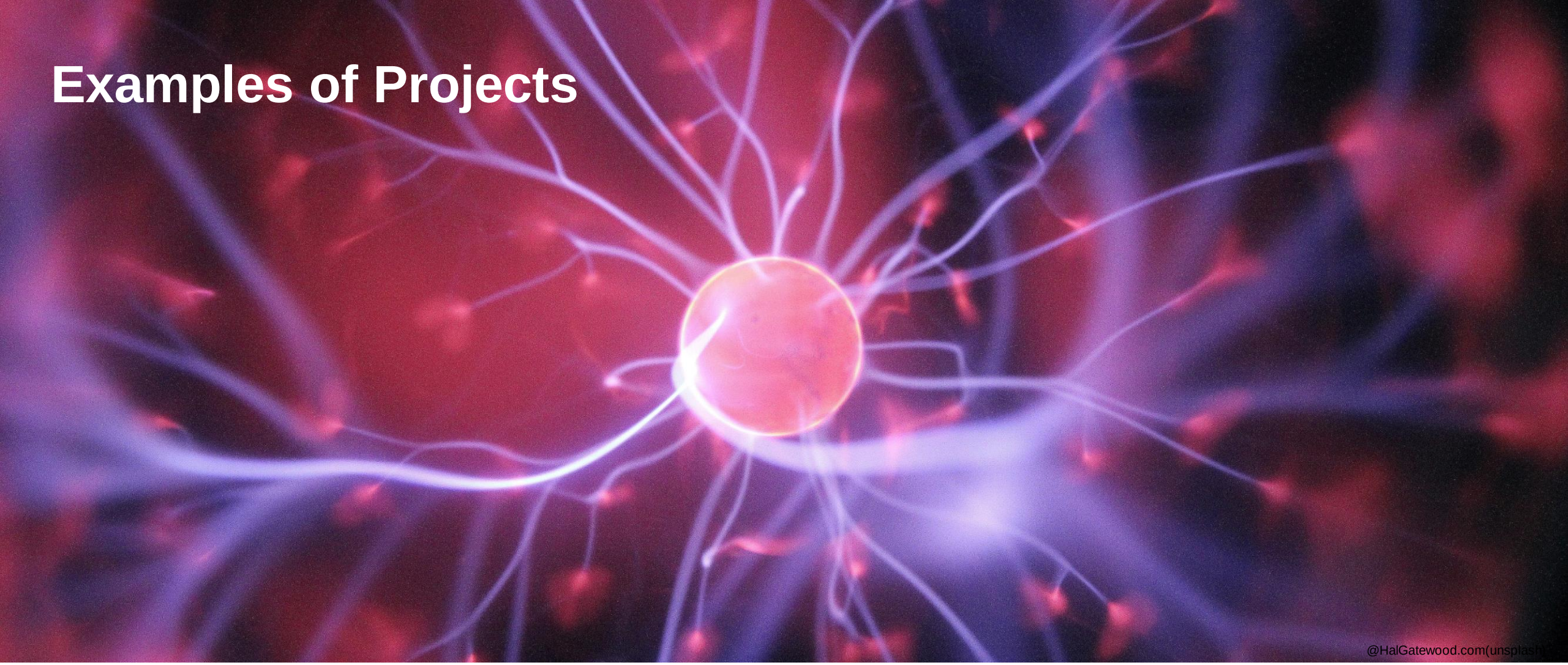
- The main focus here is on the following points:
  - Concept development
  - Circuit design and simulation (both electrical and thermal)
  - Circuit development and layout of power electronic circuits
  - Systematic commissioning of systems
  - Development of device mechanics
  - Rapid prototyping (control and mechanics)

- Among other things, new circuit approaches are analysed with regard to their practical properties. In addition, new technologies are examined with regard to their properties in existing circuit concepts.

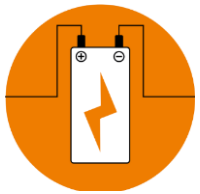
Electrical Power Supply Networks

- Asset management / grid planning and grid strategy
  - The main focus here is on decision-making under uncertain framework conditions using modular grid expansion/conversion strategies.
  - Sustainable planning strategies are applied, taking into account service life / investment and operating costs.
- Regulatory and grid management aspects of energy supply
  - All solution options, in particular smart grid and ICT options, are considered while recognising the regulatory framework conditions, in particular (unbundling) requirements. This ensures the applicability of the research.
- Grid integration of renewable energies / flexibility / ICT in the grid
  - All aspects and possibilities are explored, but always with a view to technical, legal, economic and sociological boundary conditions.
- Technical connection rules (TAR) at all voltage levels
  - As co-creator and chairman of various FNN committees, in particular the TAR-MS, the relevant aspects and their consideration are ensured
- Theoretical and practical implementation and testing of island grids
  - To increase resilience, corresponding research and field tests have been and are being carried out on real systems and distribution grids in the MW range.

Examples of Projects



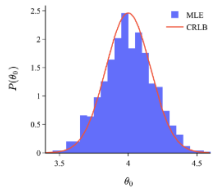
BaPoBS - Battery aging and Pareto-optimal operating strategy

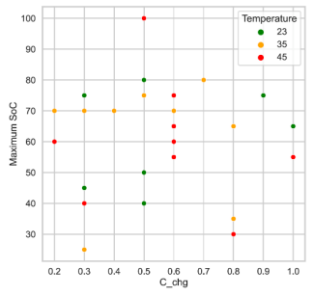


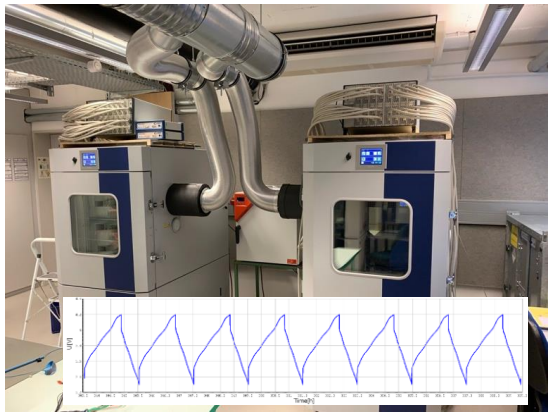
Motivation and goals

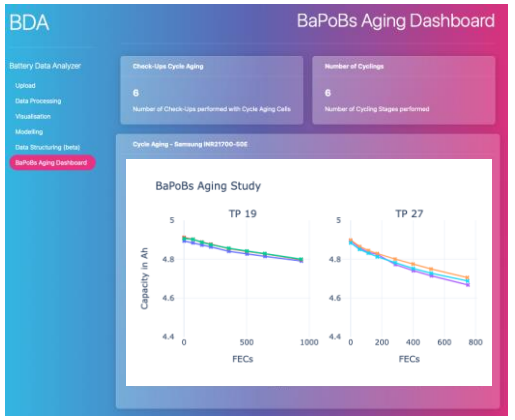
- **Operating strategies** for large stationary storage do not yet consider the impact on battery aging
  → Project goal: **reduced aging** through adapted operating strategy, **pareto-optimal trade-off** with other target variables
  → methods: Use of degrees of freedom (e.g. recharging phases during peak shaving), model-based analysis and optimization
- **Parameterization of aging models** for Li-ion batteries is extremely time-consuming and resource-intensive
  → Project goal: Optimal design of experiments, minimum effort for given accuracy of parameters
  → Methods: Minimal Parameter Variance Estimation, use of Hyper Space Exploration and Machine Learning algorithms

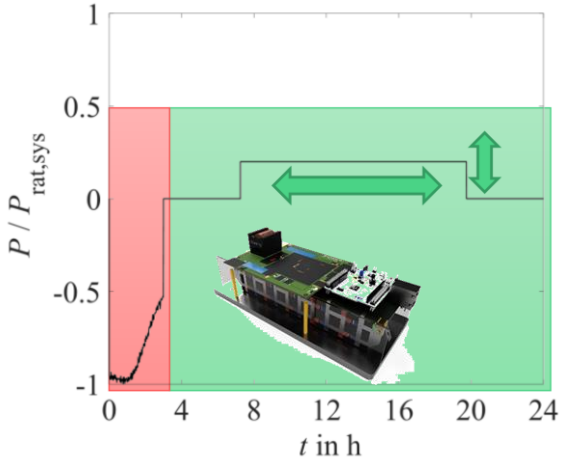
Project: duration: Dec. 2020 - Nov. 2023, BMWK, 7th German energy research program, scientific staff: F. Ströbl, F. Schaeufl









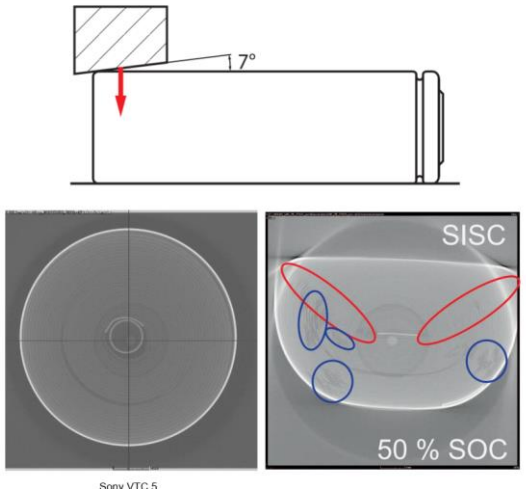


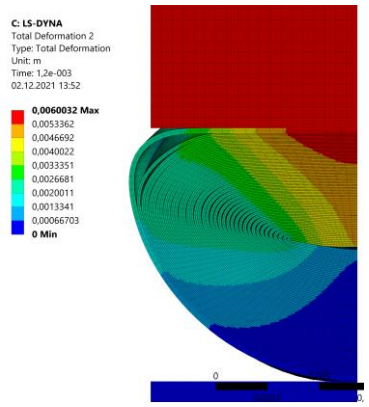
Safe-µ-Mob - Safe electric micromobility

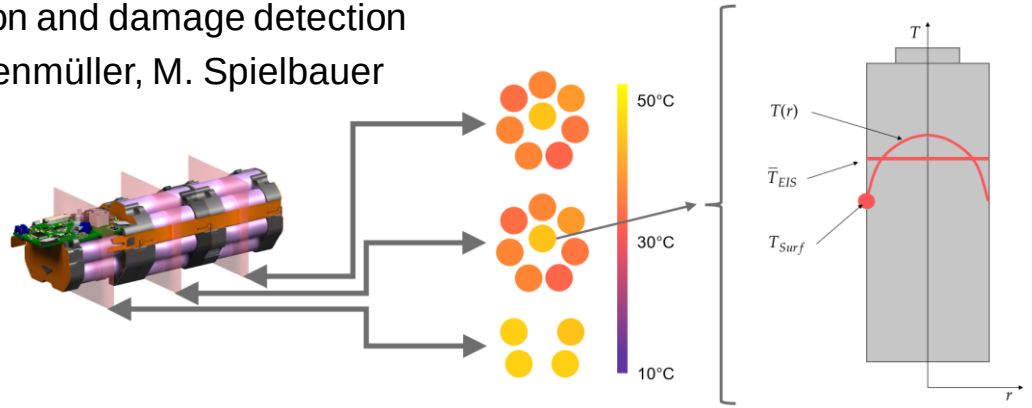
Motivation and goals

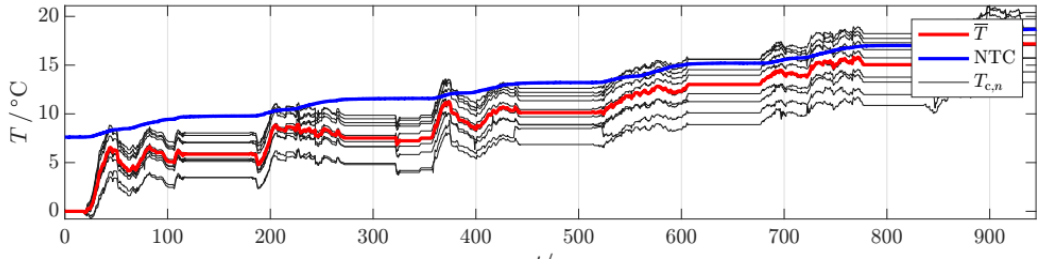
- **Li-ion batteries** for e-bikes and e-scooters are subjected to **mechanical stresses** during accidents, which can lead to mechanical **deformation of battery cells** that may remain undetected and the impact of which is unclear
  → Project Goal: To gain insights into the safety and aging behavior of damaged cells and to model them
  → Methods: Aging and safety experiments, determination of material parameters and FEM simulation, CT and EIS analyses.
- Safety-critical states with thermal events of damaged batteries often only occur during charging
  →Project goal: Innovative monitoring methods to detect possible critical states during charging
  →Methods: Online impedance spectroscopy for temperature determination and damage detection

Project: duration: Jan. 2021 - Dec. 2023, Bay. SMWK, scientific staff: C. Rosenmüller, M. Spielbauer

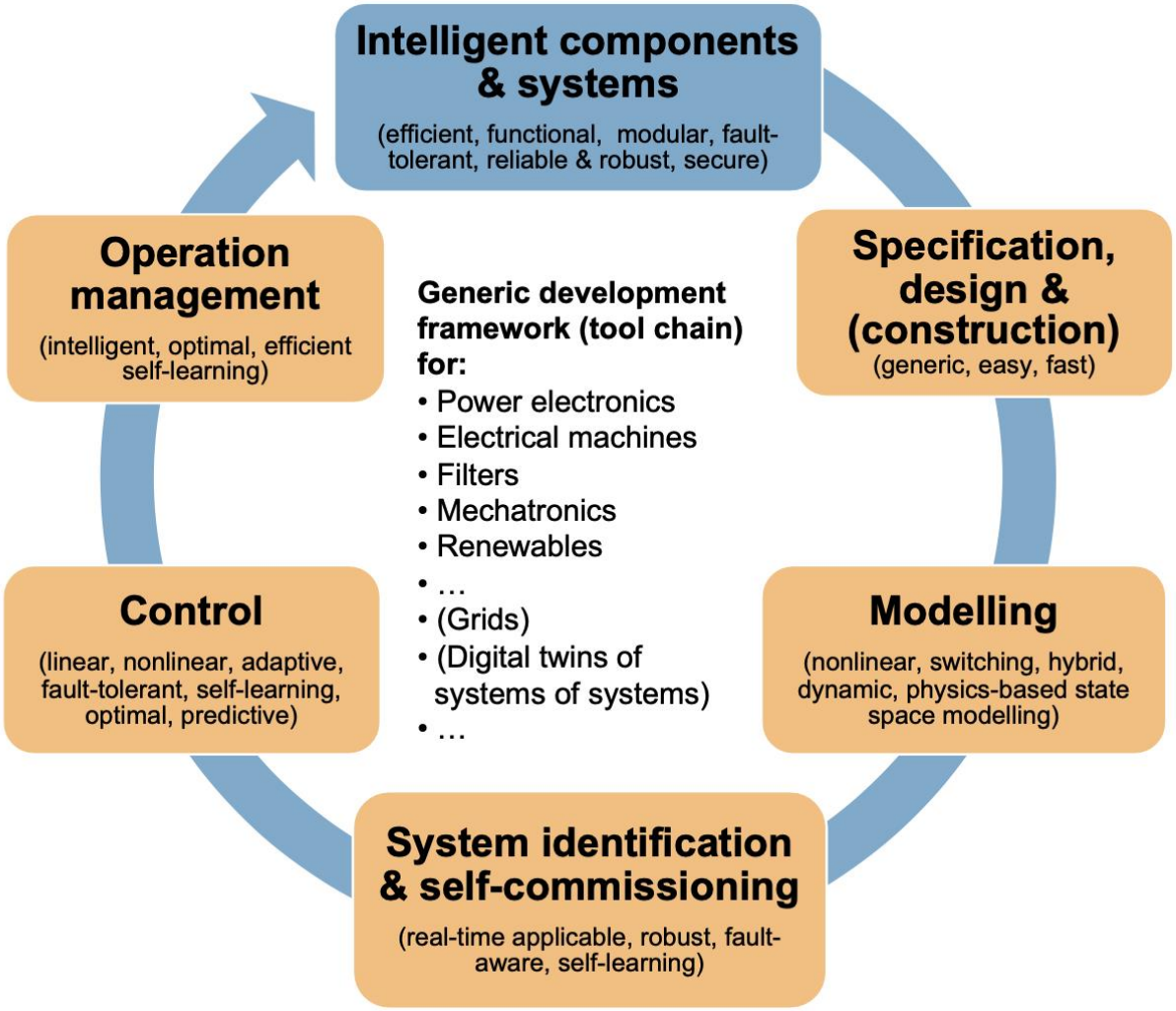




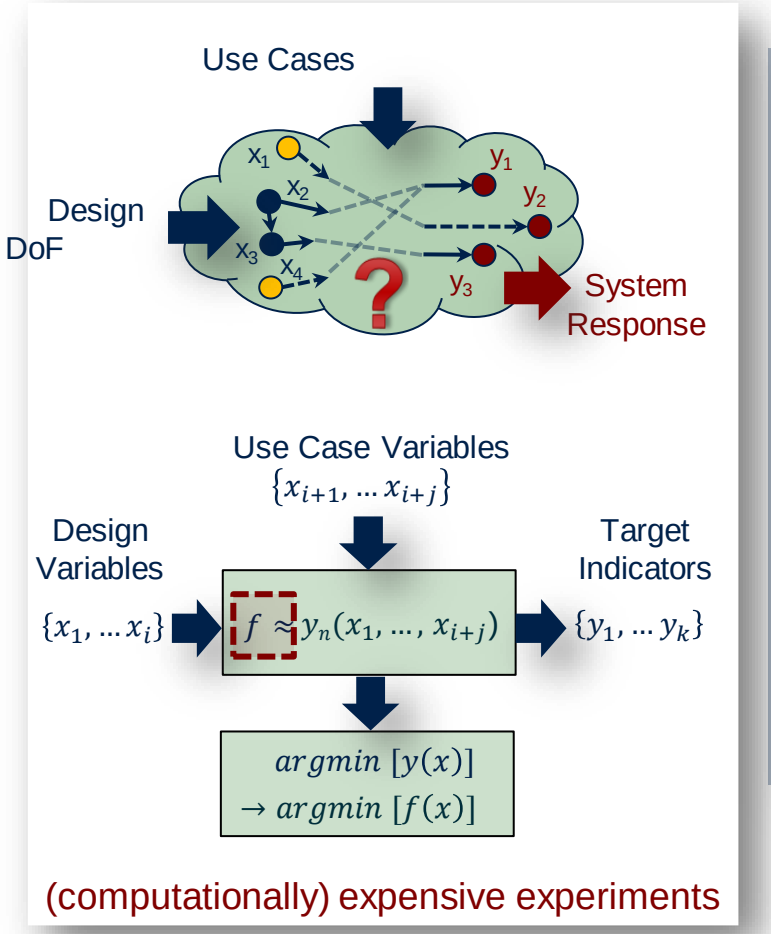


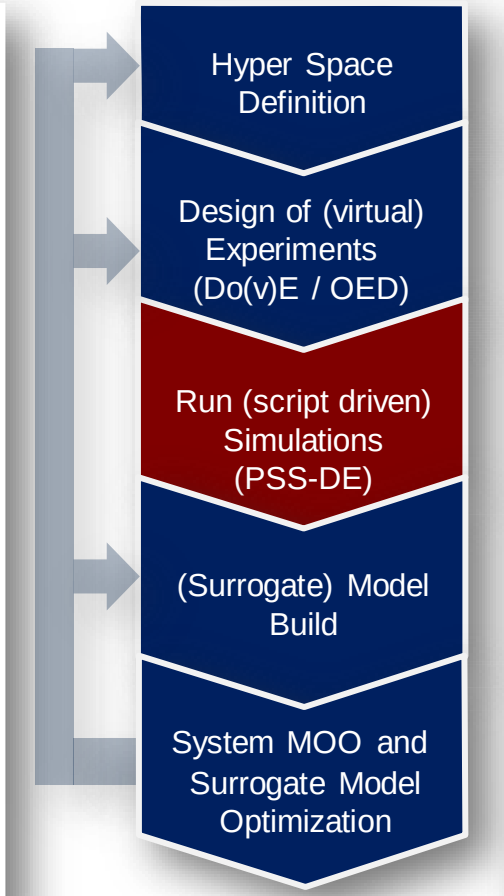


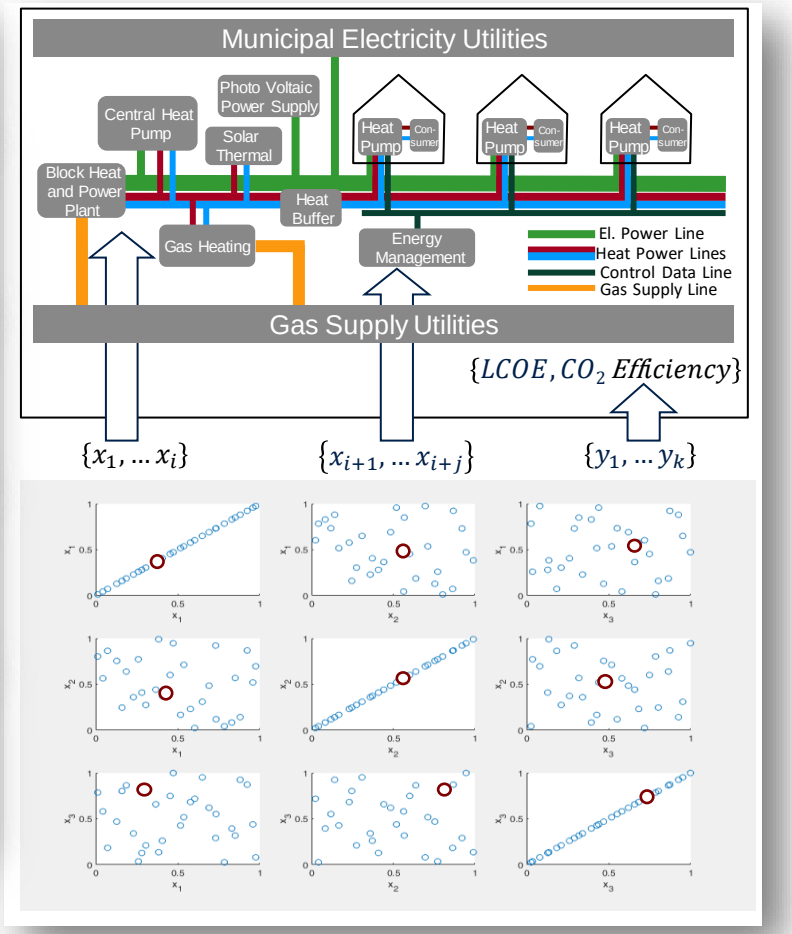
Intelligent mechatronic and regenerative energy systems



Analysis and Multi Objective Optimization Of Complex Energy Systems (ProDES)

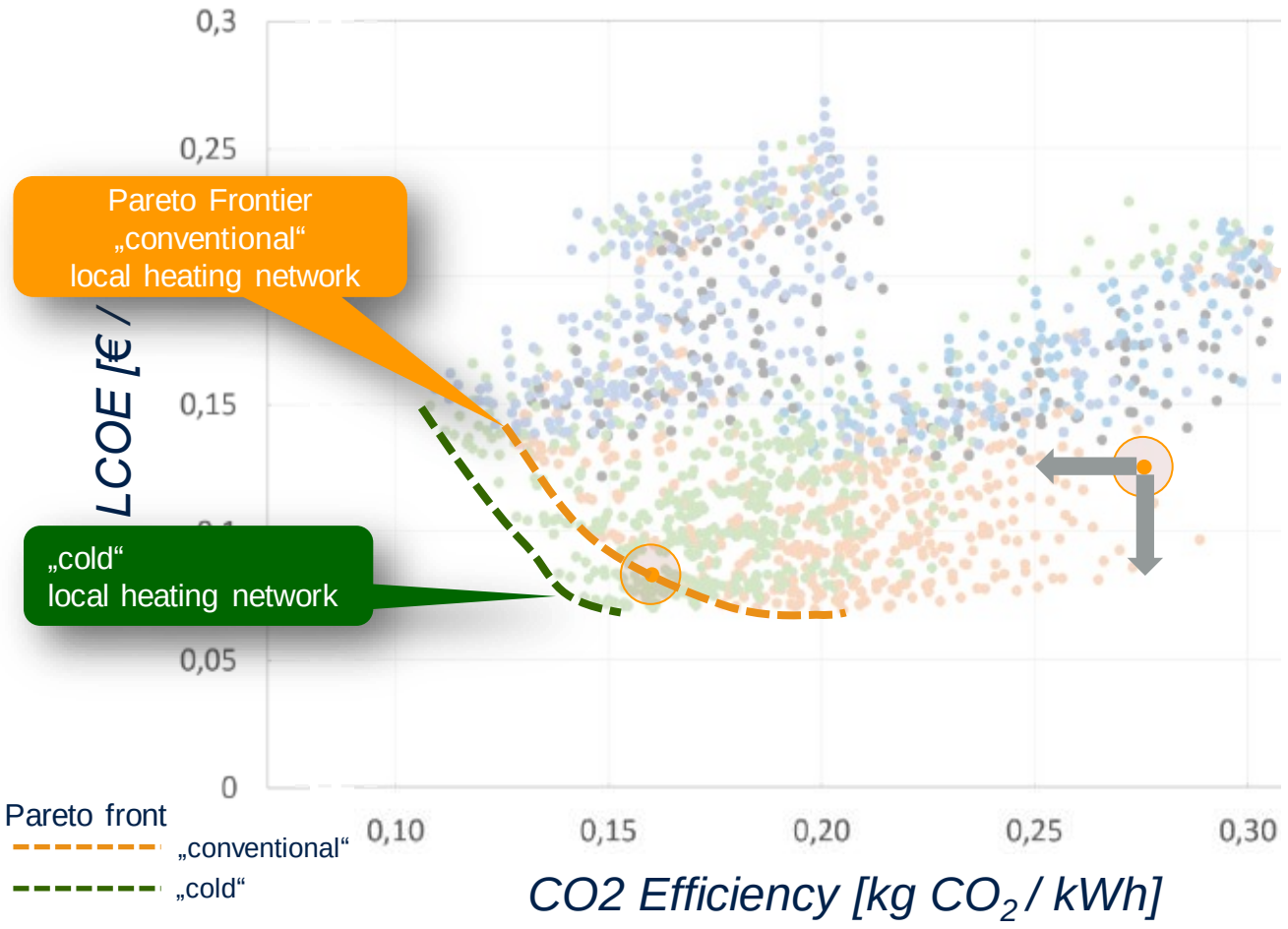






Source: H. Palm, J. Holzmann: "Hyper Space Exploration – A Multicriterial Quantitative Trade-Off Analysis for System Design in Complex Environment", IEEE International Symposium on Systems Engineering (2018)

Technology Potential is Represented by the Pareto Frontier Indicating best achievable Target Indicator Trade-offs



- 428 alternative layouts have been simulated (color: technology group)
- Only 23 simulated layouts meet criterion to be *Pareto-optimal* (PO)
- Technology Groups reveal individual Pareto-Frontiers
- Pareto-Frontier may be interpreted as „Technology Potential“
- Search algorithm as part of a dynamic search strongly affects simulation efficacy and efficiency

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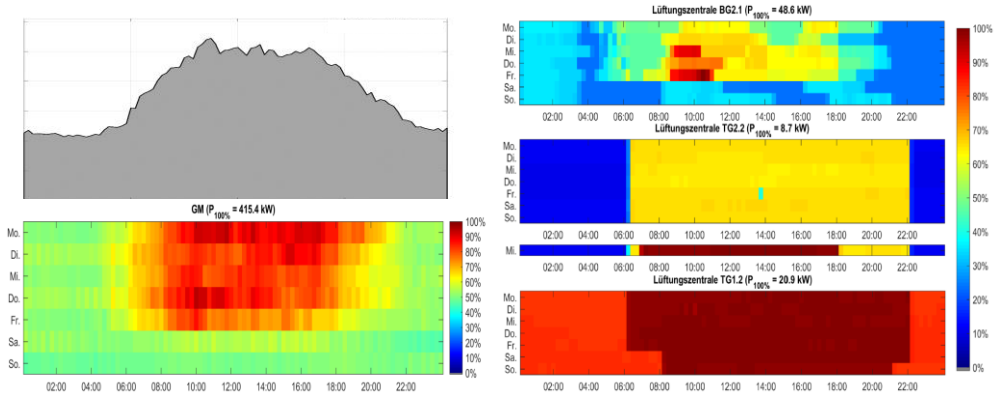
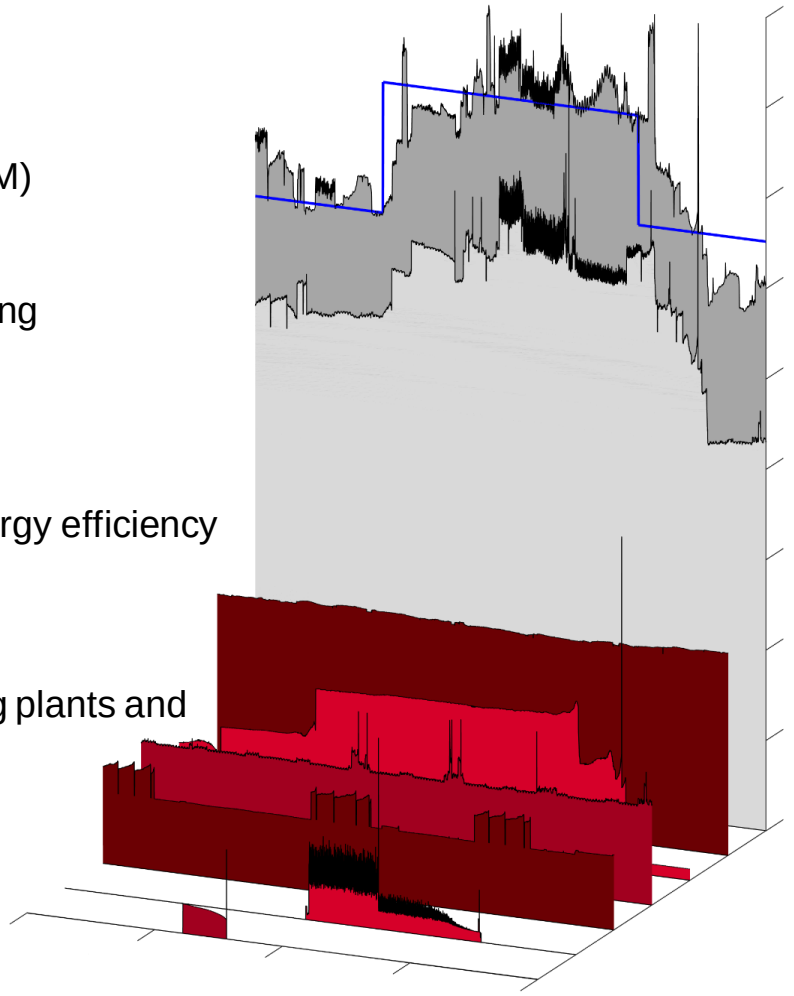
Analysis of complex building structures



Research priorities

- Non-intrusive load monitoring (NILM)
- measuring technology
- Data analysis (machine learning)
- High-resolution load profile modelling



Goals

- Analysis of complex building structures
  - •Office and administration building
  - •Industry & Craft
- Automated and data-based process
- Identification of the operating mode of essential electrical consumers on the basis of high-resolution measurement of the total consumption

Application Areas

- Energy consumption monitoring
- Identification and evaluation of energy efficiency measures
- Peak-Load reduction
- Demand Side Management (DSM)
- Design and operation of generating plants and storage facilities
- Failure detection

Supported by:

Federal Ministry for Economic Affairs and Energy

on the basis of a decision by the German Bundestag

As part of the research project:
NuData Campus - Usage Data Based Optimisation of Buildings and Facilities using the Example of Munich

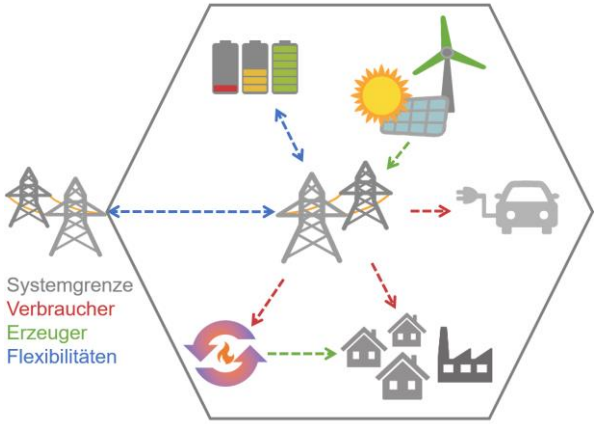
opEn – Optimal Design of Energy Cells

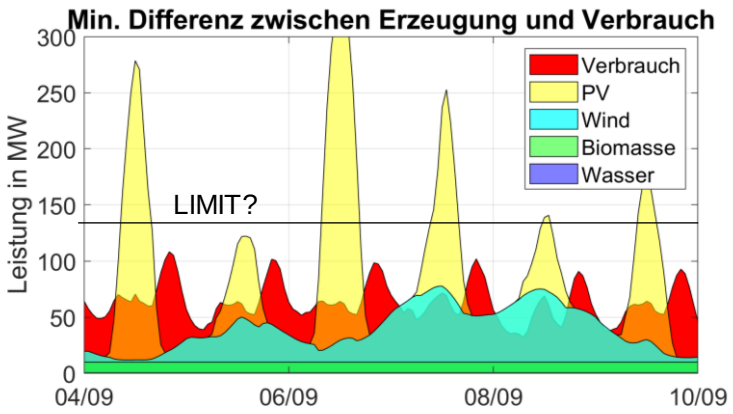
Motivation and Goals

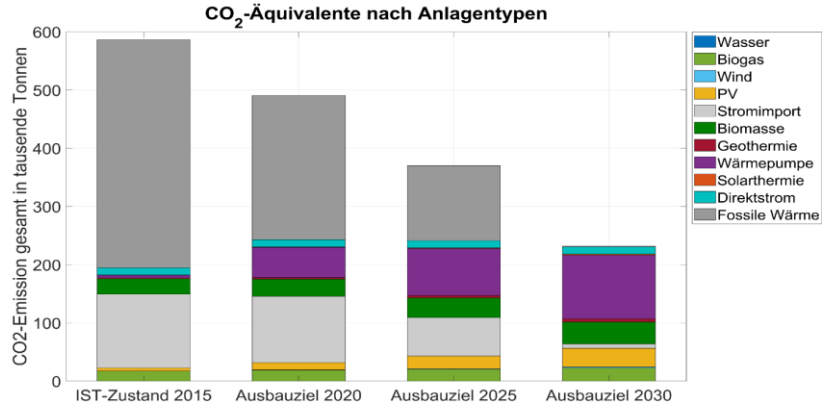
- Balance sheet planning of the energy transition insufficient, complex interrelationships, lack of (local) acceptance
- Development of a tool chain for the individual design and evaluation of energy cells with a high degree of RE expansion based on time series simulation using key figures - Operating, control and incentive concepts for the use of flexibilities - electrolysis, electromobility, storage, P2H, regulation, etc.

→ Identification and definition of suitable expansion targets and operating modes as an essential element in planning and communication/participation

- Energy cells: Counties, municipalities, energy communities - bottom-up vs. top-down?





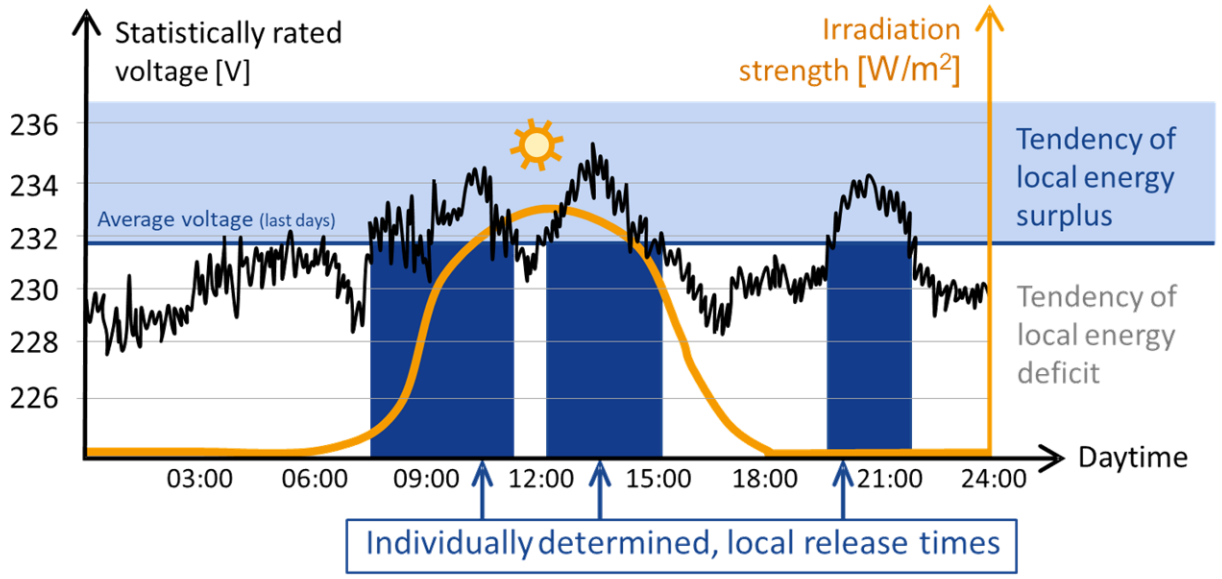


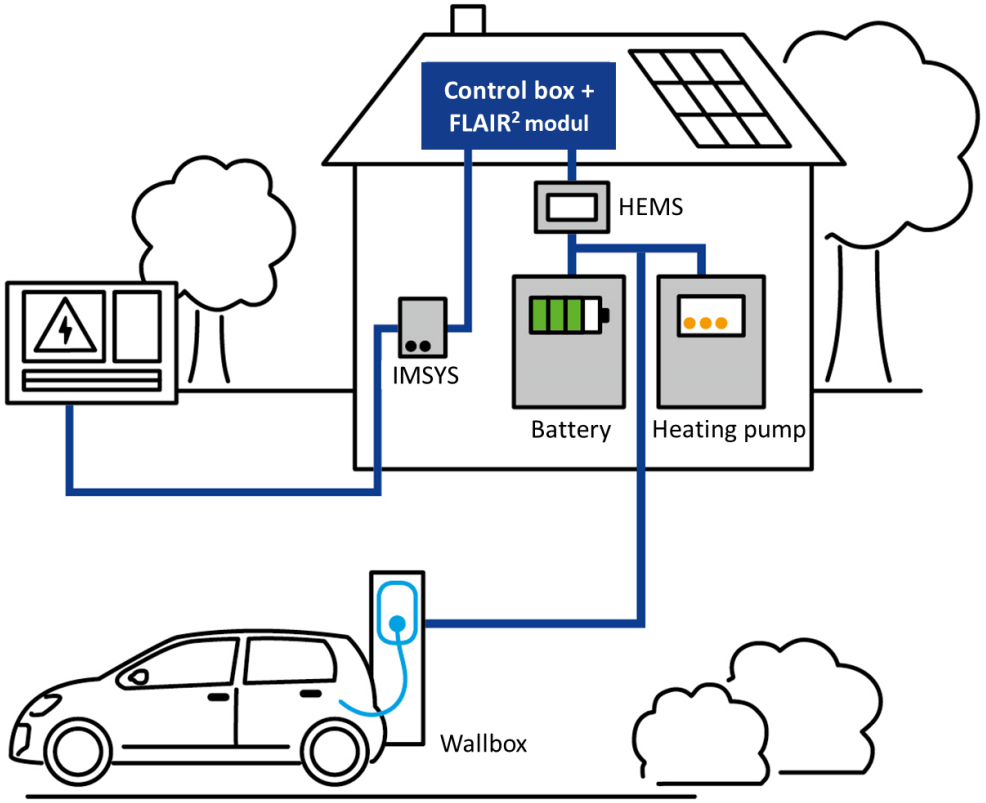
FLAIR² - Local and Automatic Control for Flexible Loads

Motivation and Goals

- Intelligent and decentralized solution to control flexible loads
- Optimization of the grid state applying demand side management
- Based on the actual and local grid state e.g. voltage measurement data

Project: Period: 2020/11 – 2023/10, Staff at HM: two research fellows

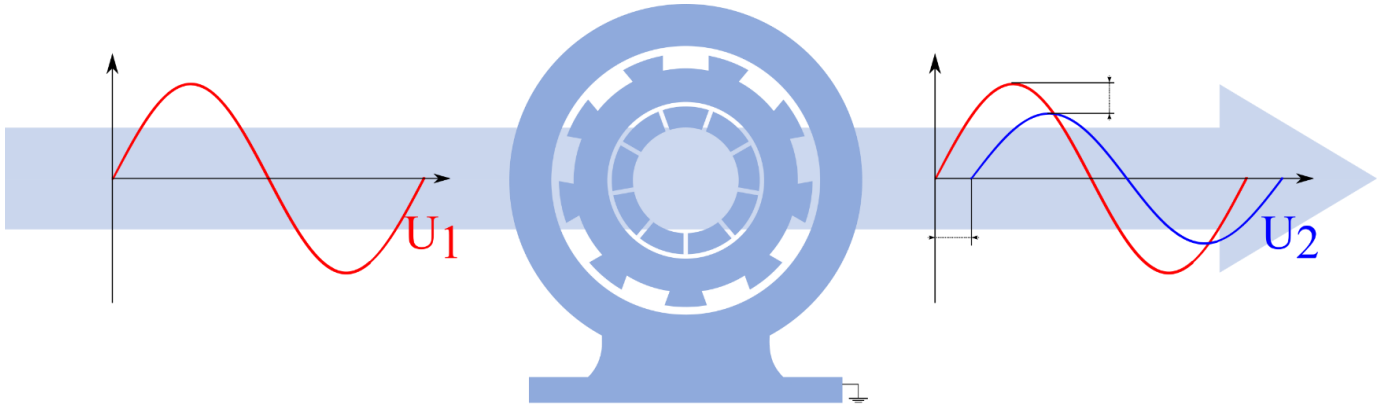




Reliable Diagnosis on Electrical Machines (CarpeDiem)

Research objectives

- Development of reproducible method for failure diagnosis on rotating machines
- Use of non-intrusive frequency response measurement and analysis (FRA)

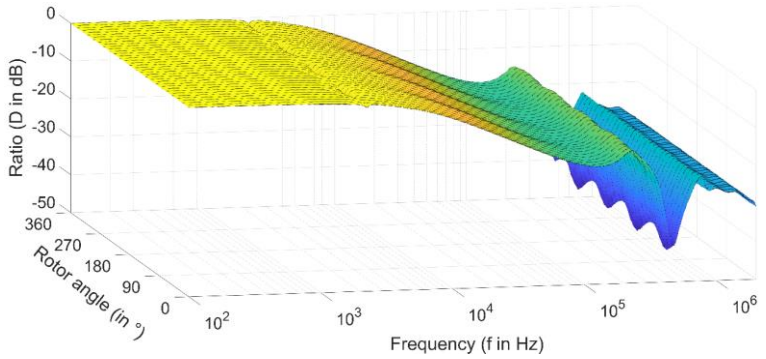


Challenges

- Finding general behavior
- Influencing factors unclear
- Assure high reproducibility
- Modeling of frequency response highly challenging

Applications

- Different types and power classes of rotating machines
- Detection of different failure modes like broken rods or shorts within windings
- Condition assessment



Project

- Period: 2020/04 – 2022/03
- Staff at HM:
  one research fellow

Detection & Localization of mechanically induced damages in lithium ion batteries (ReVISEDBatt)

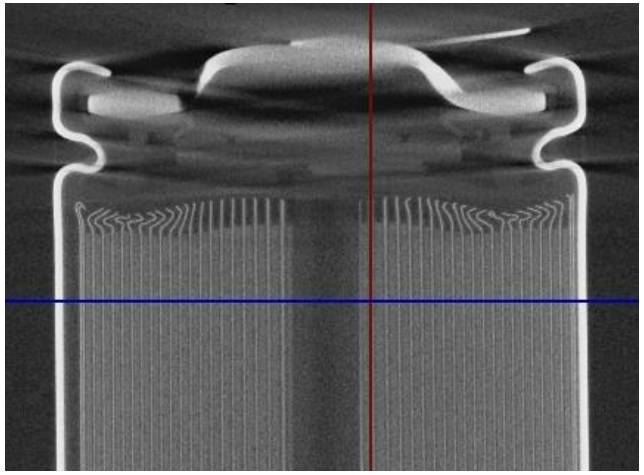
ReVISEDBatt

Research:

- Realistic mechanical stresses, such as shocks, vibrations and external forces
- Damages in cell and module components
- Effects on operational and aging behavior
- Detection methods

Objectives:

- Knowledge of damage mechanisms
- Development of novel early detection methods
- Online application in battery management systems



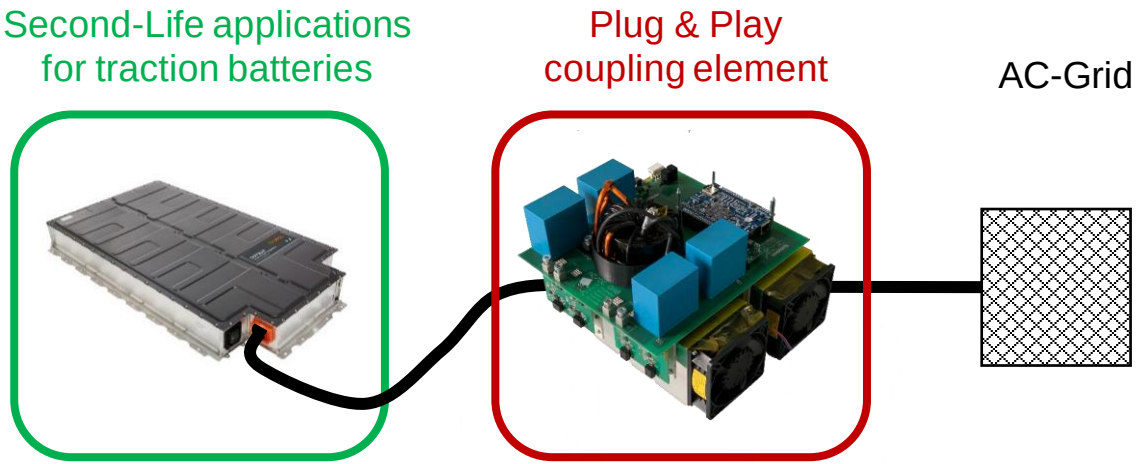
Project:

- Project period: 2017/09 – 2021/03
- Staff at HM: one research fellow, student workers

Supported by:
Federal Ministry for Economic Affairs and Energy
on the basis of a decision by the German Bundestag

Fraunhofer ISC · TÜV SÜD · thyssenkrupp · infineon · HOPPECKE · HILTI

Universal connection of automotive traction batteries for stationary applications (UnABESA)



Research objectives

- Universal architecture for different batteries and applications
- Highly efficient power electronics with innovative control
- Optimized power flow in heterogeneous battery systems

Applications

- Frequency regulation
- Peak shaving
- Decentralized storage

Challenges

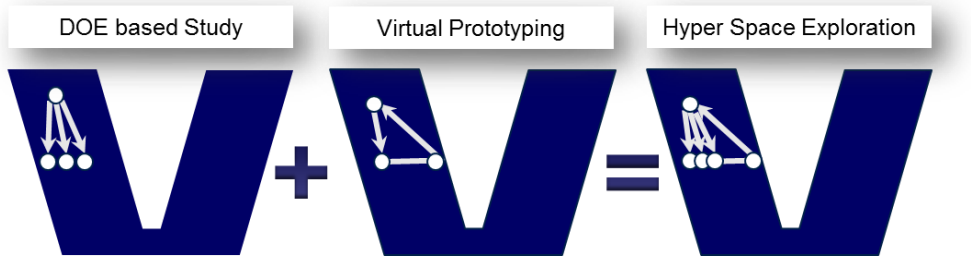
- No standardized design
- Different battery properties
- Costs

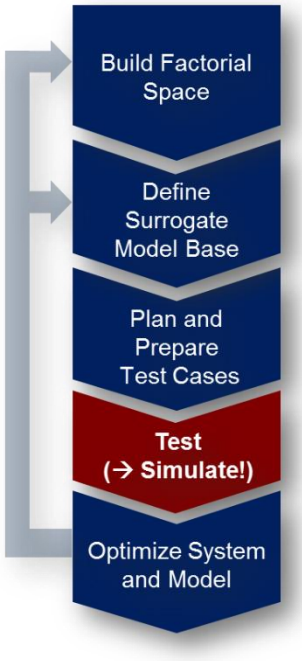
Project:

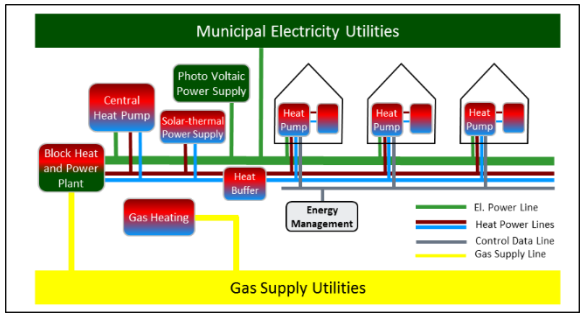
- Project period: 2017/06 – 2020/12
- Staff at HM:
  two research fellows,
  student workers

Supported by:
Federal Ministry for Economic Affairs and Energy
on the basis of a decision by the German Bundestag

Engineering of Complex Systems







- Entering new technologies involves:
  - Large amount of unknown solutions
  - Lack of „proof-of-concept“
- Extending the V-Model allows to manage related uncertainties
- „Hyper Space Exploration“ is a multi-criterial trade-off-analysis making use of:
  - Design of (virtual) experiment
  - Surrogate modelling
  - Model-driven system optimization
- Our applications:
  - Sustainable energy systems
  - Automotive top-level design (FEVs)
  - Complex Controler Design
  - Large amount of unknown solutions
  - Lack of „proof-of-concept“

Private Grid Coupling

Bundesministerium für Wirtschaft und Energie

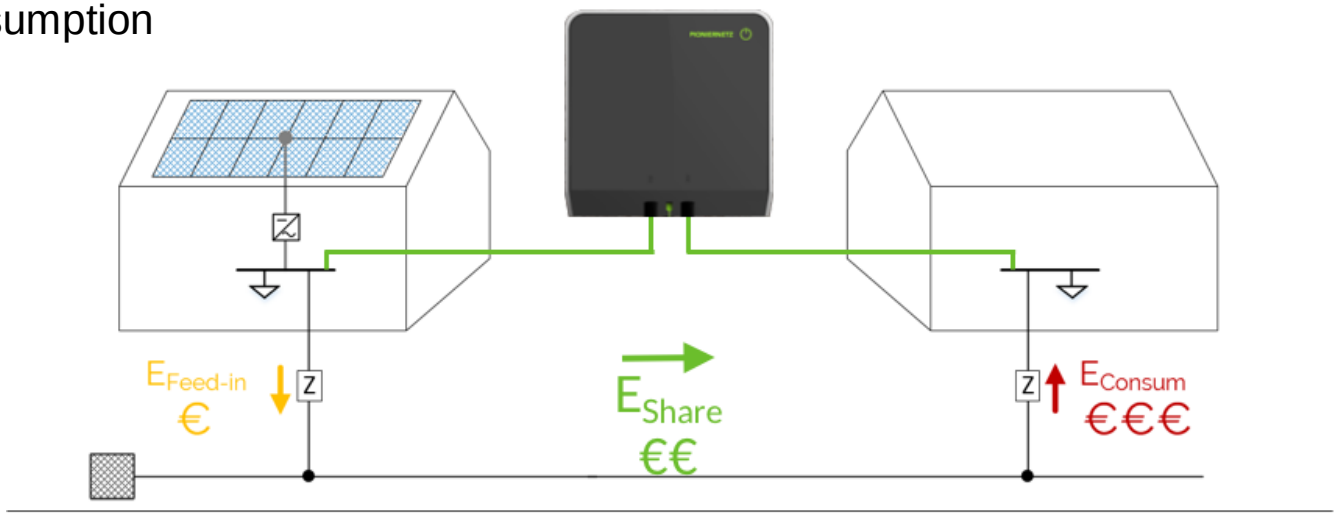
PIONIERKRAFT

Hard Facts

- Mains parallel
- Galvanic isolated
- Surplus energy transferred
- Depending on energy production and - consumption

Customer Value

- PV plant is more profitable
- economic benefits for producer and receiver
- more people get access to renewable energy.
- contribution to a successful energy revolution



Further project examples

- https://hm.edu/sites/ises/forschung_ises/projekte_ises/projekte_uebersicht_ises.en.html

Thank you!