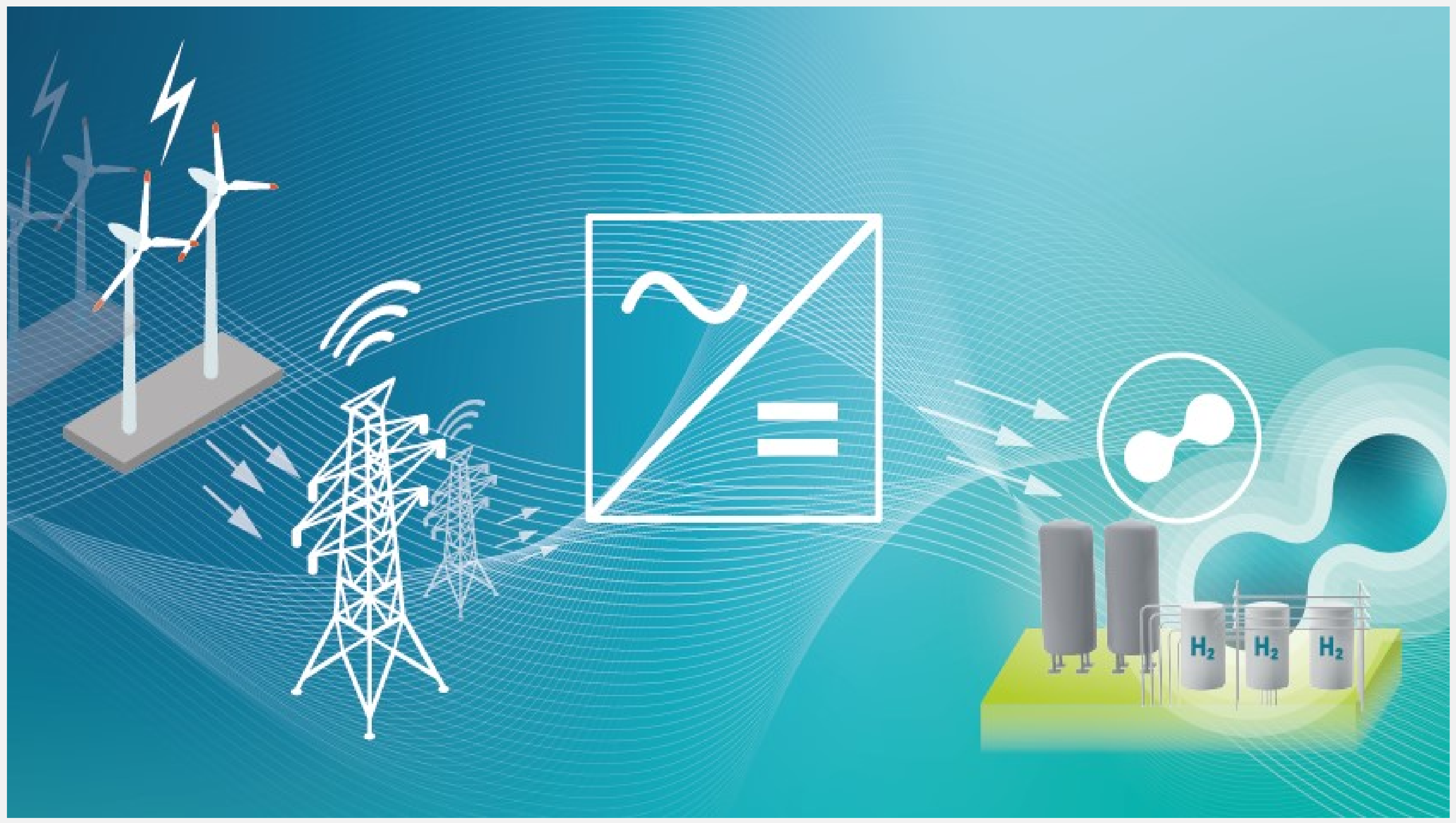


Fraunhofer IEE

DERlab European Distributed Energy Resources Laboratories

Workshop, 05. December 2023

Welcome to the workshop:
Modeling of electrolysis plants on component and system level

Workshop

Modeling of electrolysis plants on component and system level

Motivation

- Models are essential tools for the scale up of water electrolysis and hydrogen production.
- They are used to evaluate various aspects: performance and lifetime prediction, optimization of cells , automation in production, system integration of electrolysis plants or handling of fault conditions.
- For each aspect special models have to be applied.
- Some modelling approaches and applications in the flagship project H2Giga will be presented in this workshop

Aim of the workshop

- The aim of this workshop is to discuss various modelling approaches and to compile the model requirements for different use cases.
- We like to get your feedback regarding use cases for models
- Which models and tools do you need for your working environment and for the tasks you have to manage?

Fraunhofer IEE

Workshop

Modeling of electrolysis plants on component and system level

Agenda	
9:00 – 9:15	Welcome ▪ Introduction into the topic, motivation and aims of this workshop ▪ The project HyLeiT: Cost-optimized system technology and grid integration of systems for the production of green hydrogen
9:15 – 11:00	6 presentations ▪ Modelling use cases and requirements (Norbert Henze, Fraunhofer IEE) ▪ Electro-chemical and BoP models (Debraj Ghosh, Phillip Kretschmer, FraunhoferIEE) ▪ PEM electrolyser model (Ansgar Reimann, Fraunhofer IEG) ▪ Modelling of electrochemical reactors + systems in different time and spatial scales (Faisal Sedeqi, DLR) ▪ Equivalent circuit models (Michael Bruhns, Technical University Dresden) ▪ Dynamic electrical models for power grid integration (Nils Wiese, Fraunhofer IEE)
11:00 – 11:15	Questions / Answers
11:15 – 11:30	Coffee break
11:30 – 12:30	Discussions
12:30 – 13:00	Conclusions and end of meeting

Project HyLeiT

Cost-optimsed system technology and grid integration of systems for the production of green hydrogen

Project HyLeiT

Cost-optimised system technology and grid integration of systems for the production of green hydrogen

Profile

- Funding: Federal Ministry of Education and Research (BMBF)
- Part of the flagship project H2Giga: Serial Production of Electrolysers
- Duration: 01.04.2021 – 31.03.2025
- Project Partner
  - Fraunhofer IEE (Project lead)
  - SMA Technologies AG
  - Infineon AG
  - Technical University Dresden
  - University Bonn-Rhein-Sieg

Content and objectives

- Project content
  - Development of system-optimised rectifiers
  - Investigation of electrolysis stacks to build real-time simulation models for optimal power converter design
  - Grid integration of electrolysis plants (grid support, system services)
- Key objectives
  - New generation of power inverters for electrolysis plants
  - Cost reduction in system technology
  - Better DC power quality for the electrolyser
  - Grid compatibility and options for system services
  - Embedding in scenarios with 100% RE

Project HyLeiT

Classification within the flagship project H2Giga

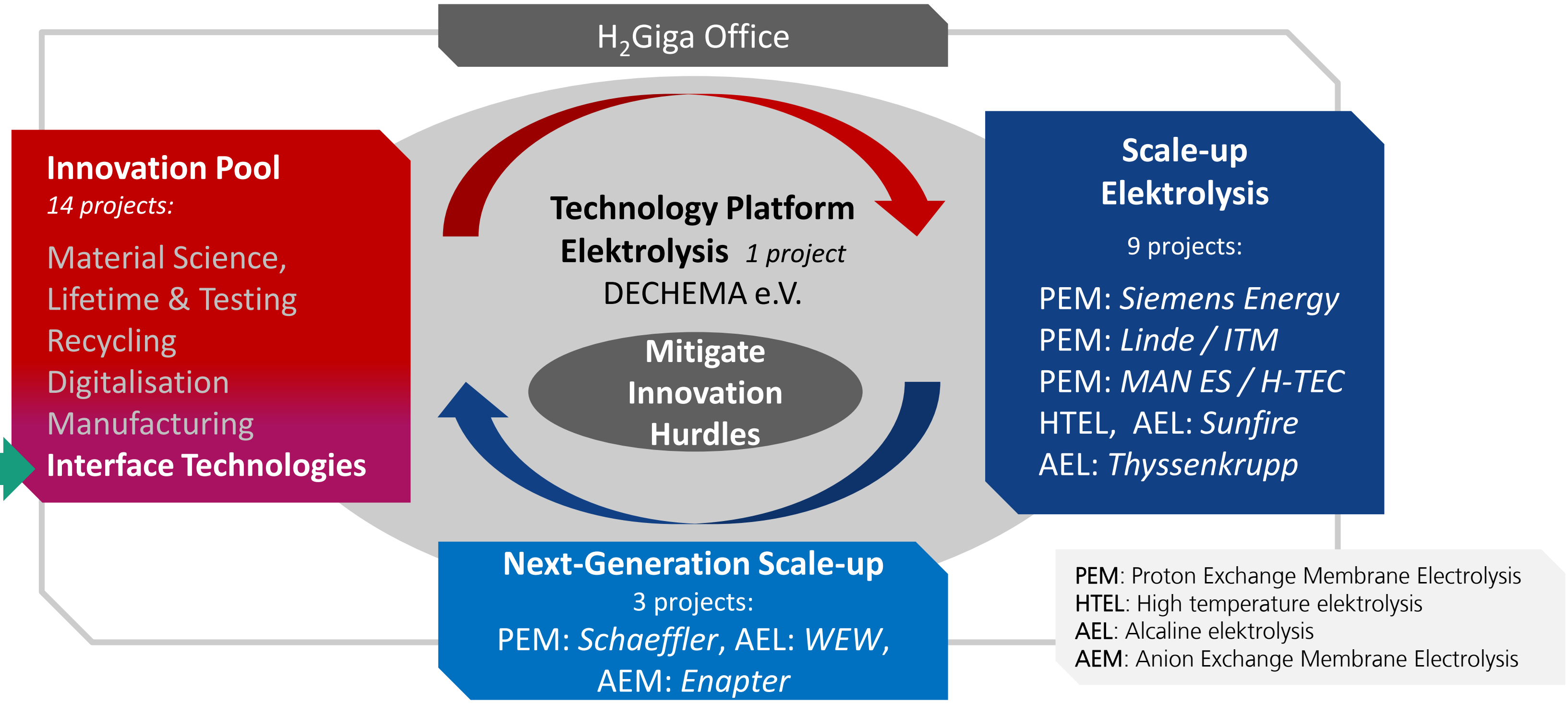
Înnovation pool

→ **Interface technologies**

HyLeiT

→ **Power supply technologies for electrolysers**

- Fraunhofer IEE (Project lead)
- SMA Technologies AG
- Infineon AG
- Technical University Dresden
- University Bonn-Rhein-Sieg



Source: DECHEMA e.V.

Project HyLeiT

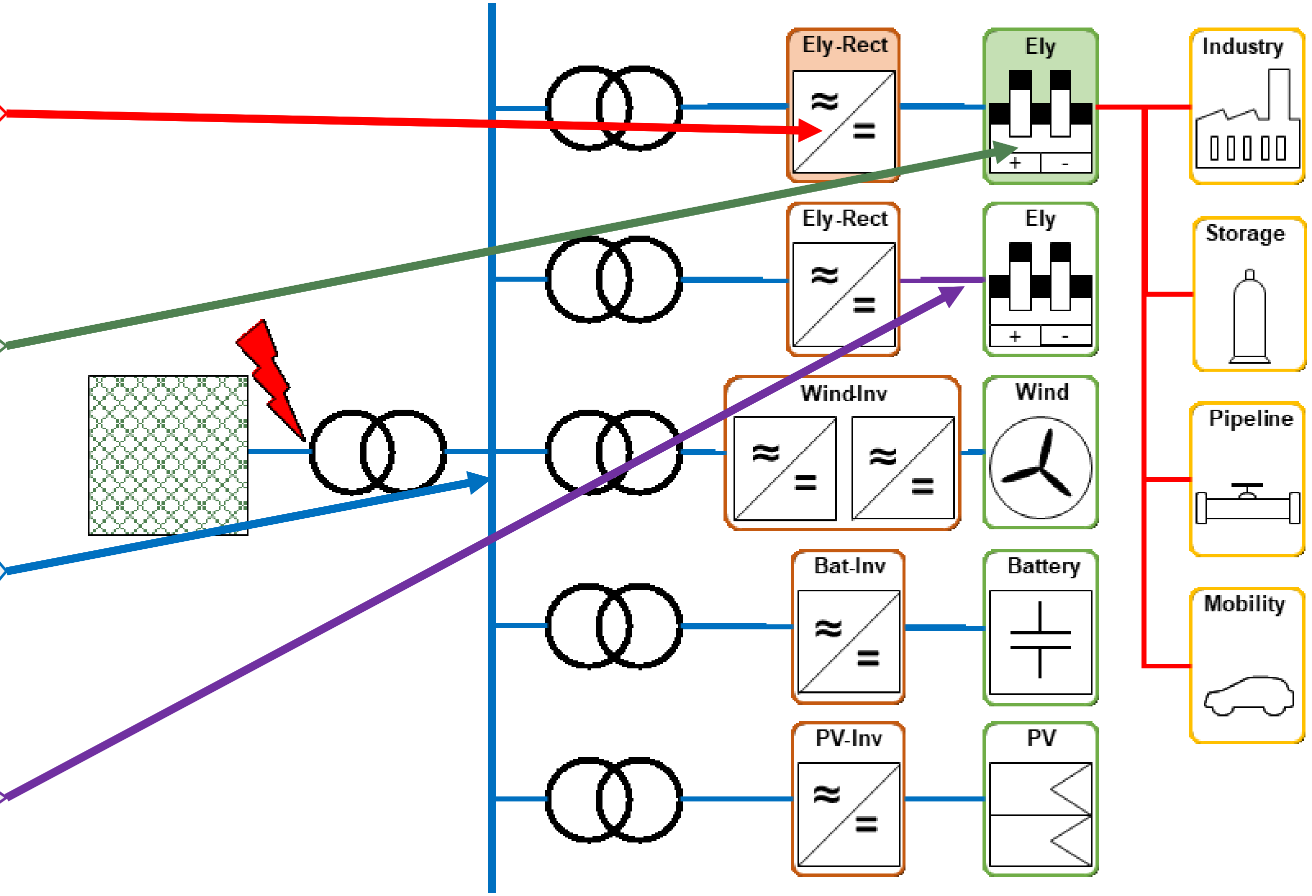
Activities in electrolysis systems

- Development of optimised inverters
- Examination of the connection technology
- Development of a system protection concept

- Development of cell and stack models taking BoP into account

- Modeling of the whole electrolysis power system
- Modeling of the areal grid and higher-level grids

- High current connections
- Behavior during faults



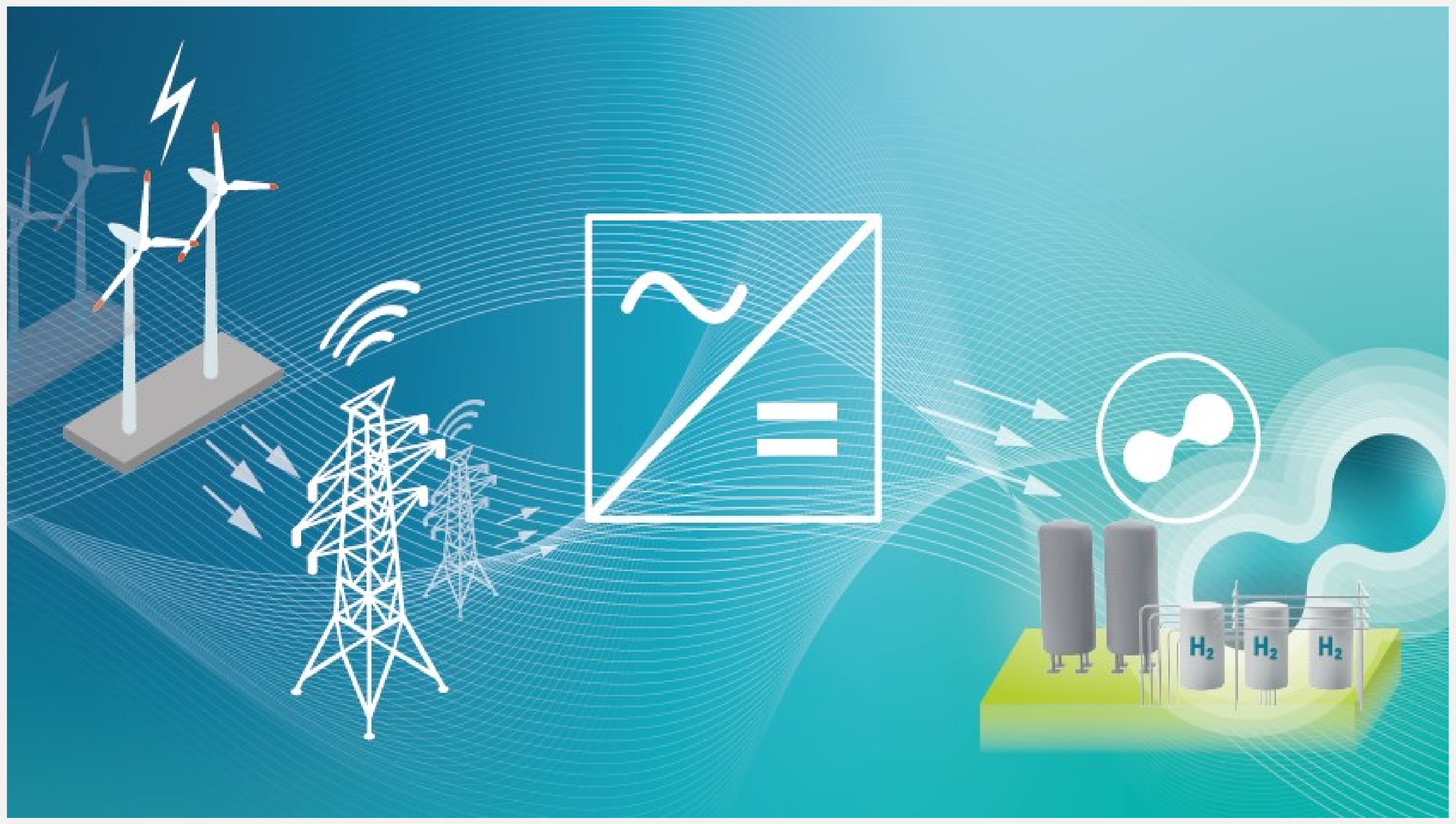
 08.12.2023

Fraunhofer IEE

Workshop

Presentations

- Modelling use cases and requirements (Norbert Henze, Fraunhofer IEE)
- Electro-chemical and BoP models (Debraj Ghosh, Phillip Kretschmer, Fraunhofer IEE)
- PEM electrolyser model (Ansgar Reimann, Fraunhofer IEG)
- Modelling of electrochemical reactors + systems in different time and spatial scales (Faisal Sedeqi, DLR)
- Dynamic electrical models for power grid integration (Nils Wiese, Fraunhofer IEE)
- Equivalent circuit models (Michael Bruhns, Technical University Dresden)



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DERlab
European Distributed Energy Resources Laboratories

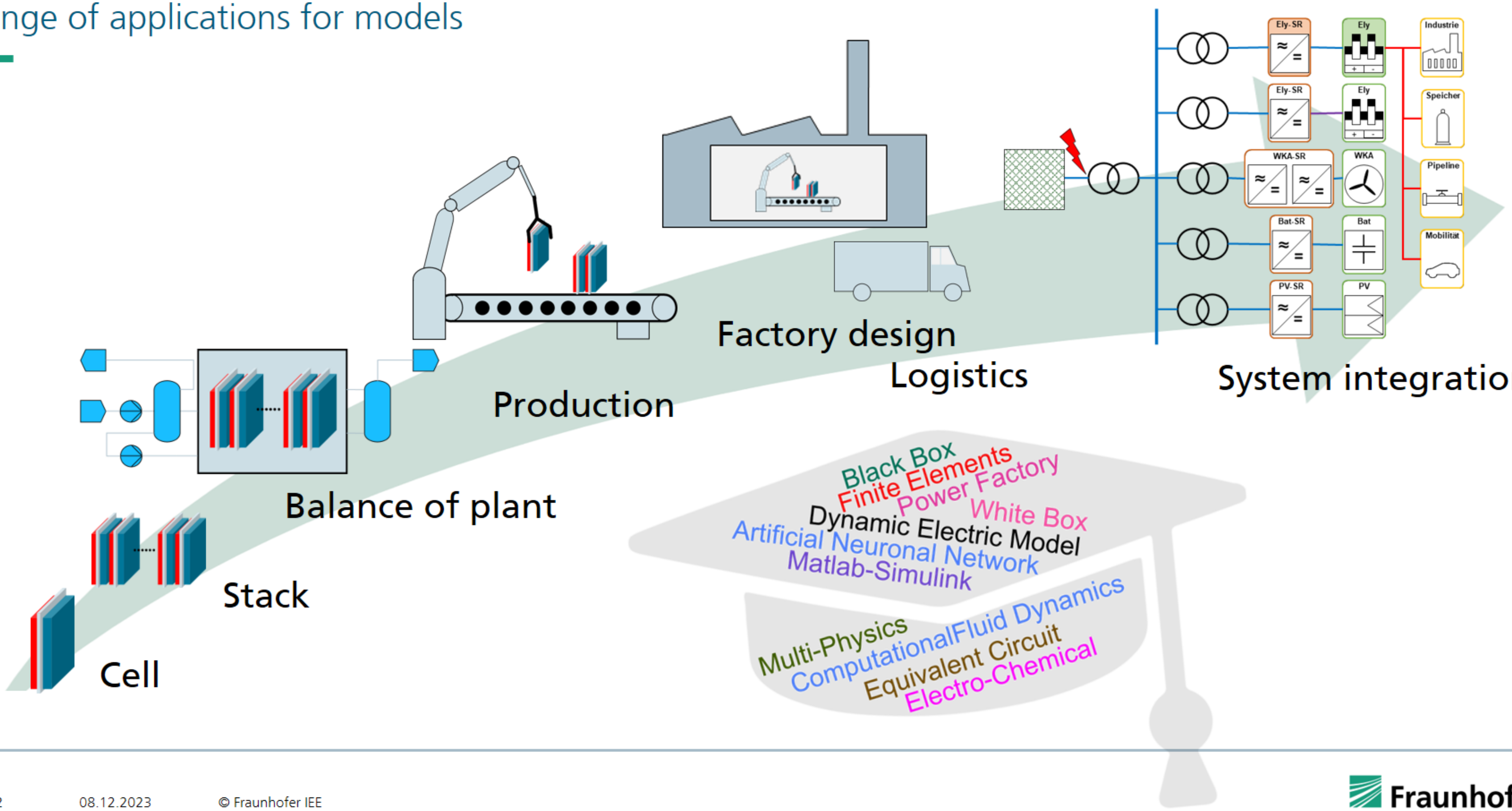
Workshop, 05. December 2023: Modelling of electrolysis plants on component and system level

Norbert Henze (Fraunhofer IEE):

Modelling use cases and requirements

Modelling of electrolysis plants on component and system level

Range of applications for models



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Modelling of electrolysis plants on component and system level

Exemplary use cases

Research & development

Modelling of electro-chemical processes
- Impact of materials, membrane,…
- Impact of operating conditions (temperature, pressure,..)
- Impact of geometric condition

CFD + FEM modelling
- Simulation and optimisation of e.g. bipolar plates (BPP) and porous transport layers (PTL)

Production

Modelling and simulation of production processes
- Up scaling from lab conditions to industrial conditions
- Digital twins of products, factories and hydrogen plants

System integration & operation

Dynamic electric models Equivalent circuit models
- Rectifier models establishing the link between grid and stacks
- Grid integration studies of electrolysis plants (Grid code compl., eval. of grid services)
- Evaluation of operation under fault conditions (short circuits)

Component and system models
- Simulation and optimisation of components and systems in terms of economy, sustainability and stability (e.g. value added chain)

Modelling of electrolysis plants on component and system level

Aims of modelling

Exemplary aims of modelling	Modelling approach
▪ Optimal cell design for high power density ▪ Impact of operation modes on stack performance and degradation ▪ Evaluation of mechanical stress solid oxide electrolysis cells	▪ Electro-chemical models mapping chemical and physical processes. ▪ 3D-electro-chemical-mechanical models
▪ Degradation model for lifetime analysis ▪ Precise prediction of lifetime	▪ Machine learning ▪ Quantum computing
▪ Higher product quality and precise specification matching ▪ Less effort for qualification tests ▪ Interfaces for distributed production	▪ Digital twins of components ▪ Digital twins of factories ▪ Feedback of field data of existing plants in product development
▪ Evaluation of grid code compliance ▪ Assessment of grid stability in inverter dominated grids (with RE) ▪ Provision of system services (e.g. instantaneous reserve)	▪ Dynamic electrical models

Modelling of electrolysis plants on component and system level

Conclusion

Models are essential for the scale up of water electrolysis and hydrogen production

- **Prospects of laboratory tests are limited.**
  - Not everything can be examined in the laboratory with reasonable effort.
  - You don't want to test fault scenarios in multi-MW systems in reality. However, you have to know how to deal with it.
  - Model based tools are required for research and development
- **Lifetime prediction and predicted maintaining under consideration of flexible operation requires precise models**
- **With the ramp up, electrolysis plant are becoming system relevant loads in the electricity grid.**
  - Stability evaluations and grid code compliance need to be preformed by means of model based grid integration studies.
- **In combination with volatile renewable energies electrolysis plant may be operated flexible and dynamically.**
  - Operation conditions may impact the gas quality and composition. Emergency stop (e.g. due to high share of O_2 in produced hydrogen) should be avoided. Process optimisation can be supported by means of simulation.

Modelling of electrolysis plants on component and system level

Questions, Discussion

Interactive part (Response by hand signal in TEAMS):

- Participants from Industry: 8
- Participants from academia: 20

- Interested in Cells / Stack modelling
  - Industry: 11
  - Academia: 20

- Interested in system failures / system protection
- Industry: 9
- Academia: 9

- Interested in grid integration:
  - Industry: 6
  - Academia: 20

Modelling of electrolysis plants on component and system level

Questions, Discussion

- **What are the most relevant use cases for models in electrolysis (development, production, monitoring, performance prediction, system integration, etc.).**
- **What effects should be represented by the models (normal operation, aging, system failures, etc.)?**
- **What requirements are made for the models (e.g. in terms of dynamics, real-time capability, normal operation, error scenarios, etc.)?**
- **Where is the specific benefit of using models (cost savings, development time, plant monitoring, safety aspects, etc.)?**

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