**2nd Workshop on Simulation-based Research for the Energy Sector –**

**Opportunities and Possibilities of the Finite Element Method**

**Oct. 26th 2023 | 09:00 am – 01:00 pm**

| Schedule | Topic | Presenter |
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| 09:00 - 09:15 | **Welcome**<br>• Short portrait ISE<br>• Overview of PV value chain with application examples shown later and introduction of presenters<br>• Overview of simulation software/hardware used at ISE | Dr. -Ing. Andreas Beinert, Finite Element Methods & Yannic Hirschburger, Battery Engineering |
| **09:15 – 10:35** | **Photovoltaics** | |
| 09:15- 09:35 | "Rinsing processes for the production of silicon solar cells: A numerical and experimental investigation"<br>Potential improvements for the rinsing process of Si wafers are identified by numerical simulations. A model was developed which describes the concentration distribution near the wafer surface of potassium hydroxide (KOH) as a function of time, temperature, volume flow, wafer size and gap distance between the wafers. It was found that the rinsing process can be divided into two phases: The diffusion of the chemicals from the surface in the flow field and the transport of the chemicals by the rinsing water. In contrast to constant low-flow rinsing, the combination of a phase without flow and subsequent high flow saved 35 seconds of process time. The simulation results were transferred to experimental rinse recipes. With regards to the flow conditions two different inlet pipes, an industrial standard and an optimized pipe are compared using three different recipes. | Dr. Martin Zimmer, Head of Group Wet chemical Proceses |
| 09:35 – 09:55 | "Effects of structural changes in metal meshes on flow through shear-thinning fluids using CFD simulation"<br>The metallization of silicon solar cells by screen printing is a widespread and stable process. However, it involves an extensive parameter space, which must be adjusted when a single parameter is changed in order to continue to achieve the optimum printing result. In this talk we present the transfer of a 2-dimensional mathematical model of a screen mesh to a 3-dimensional space. For this purpose, a CFD simulation was developed, which is linked to the mathematical model via an interface and can communicate. The system aims at optimizing parameter combinations of the screen printing process by means of specific parameter variations and iteration runs. Selected simulation runs are verified with identical parameter combinations at laboratory scale. Information on aging and defect incidence in screen meshes over their lifetime are incorporated into the model. Cost-intensive iteration processes for parameter optimization of the screen printing process can thus be carried out in digital space in the future. | Tom Hoger, Printing Technology |
| 09:55 – 10:15 | "Assessment of the lift-off risk for vertical-installed PV modules on flat-roofs using CFD simulations"<br>PV modules installed on flat roofs are usually fixed using ballast, because the outer roof skin should not be penetrated. However, for roofs with a low maximum allowed weight, this might not be a suitable solution. Therefore, a ballast-free installation is needed. In this study, we use CFD simulations to assess the risk for ballast-free vertical installed PV modules to be shifted by wind load. For this purpose different wind directions are simulated and the resulting force on the PV system is calculated. | Francisco Torres, Concentrating Collectors and Optics |

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| 10:15 – 10:35 | "Effects of inhomogeneous loads on PV modules"<br><br>In contrast to homogeneous mechanical load according to IEC 61215, photovoltaic modules in the field are mainly exposed to inhomogeneous loads like snow or wind. Using computational fluid dynamics and finite element method such loads can be simulated and the effect on PV modules visualized. Another major difference between the standardized homogeneous mechanical load at room temperature to the actual load occurring in the field is the temperature, especially for snow loads. The encapsulants have a strong temperature dependency, which affect the thermomechanical behavior of the PV module. In this presentation we will give insights in how inhomogeneous loads at different temperatures affect the reliability of a PV module and present thermomechanical rules to build more robust modules. | Pascal Romer, Finite Element Method |
| **10:35-10:50** | **break** | |
| **10:50 – 11:50** | **Energy technology and Energy systems** | |
| 10:50 – 11:10 | "Secondary reflector design of beam-down solar towers"<br><br>The objective of the work is to assess the impact of implementing steel reflectors in a beam-down solar towers over the state of the art Aluminum reflectors using Finite Element Analysis (FEA) and Raytracing simulations. For this, parameters such as the solar flux density on the secondary reflectors, the temperature profile, the deformation caused by temperature and gravity are calculated for different design cases and its impact on the optical efficiency is determined. | Francisco Torres, Concentrating Collectors and Optics |
| 11:10 – 11:30 | "Evaluation of Charging Systems for Heat Storage with Coupled Heat Pump"<br><br>For an efficient operation of fluid based sensible heat storages a pronounced temperature stratification must be achieved. With coupled heat and flow simulations charging systems can be designed for an optimized stratification. In this presentation, investigations of a storage system with directly coupled heat pumps are presented and optimization possibilities are derived. | Sebastian Gamisch, Head of Group Heat and Cold Storage |
| 11:30 - 11:50 | "Heat and Mass Transfer in Thermal Applications: Simulation and Experiments"<br><br>Coupled heat and mass transfer together with fluid dynamics play a vital role in the simulation of specialized heat exchangers. Based on the example of a heat release device for a novel solar-thermal photochemical heating system, the usage of Comsol for heat exchanger evaluation and optimization will be presented. | Dr. Andreas Velte-Schäfer, Thermal Integration |
| **11:50-12:00** | **Break** | |
| **12:00 – 12:40** | **Battery** | |
| 12:00 – 12:20 | "Electrochemical characterization of a battery cell and its simulative mapping in the module."<br><br>In this presentation, the possibilities of electrical and thermal | Yannic Hirschburger, Battery Engineering |

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| | characterization of a battery cell in our battery laboratory are presented. Based on the laboratory results, an electrothermal FEM simulation model of a battery cell is presented, as well as its accuracy. The model of a single battery is used to show the single cell behavior of parallel connected batteries inside a module. The optimization potential of the module components will also be shown, in order to provide battery cells with the most uniform current possible. | |
| 12:20 – 12:40 | "Advancing battery safety: simulation-based development of test bench and its supplementary components"<br><br>The safety issues of Li-Ion batteries play an increasingly important role. For the deep understanding of ongoing processes during thermal runaway and their consequences, for an estimation of some non-measurable values like for example amount of released energy, its distribution over different energy transmission paths, or gas flow rate at different positions around the cell, an interplay between experimental measurement and FEM simulations are essential. That is why besides pure simulative mapping of thermal behavior of the cell its environment must be included. This presentation gives a short overview of involved test bench, FEM model of cell during thermal event and its embedding into the simplified representation of the testing environment. All operating modes of test bench, test preparation via inertization, test execution via thermal event, heat dissipation, and end of test are addressed. | Keval Brahmbhat, Battery Engineering |
| **12:40 – 13:00** | **Summery and feedback** | Dr. -Ing. Andreas Beinert, Finite Element Methods & Yannic Hirschburger, Battery Engineering |