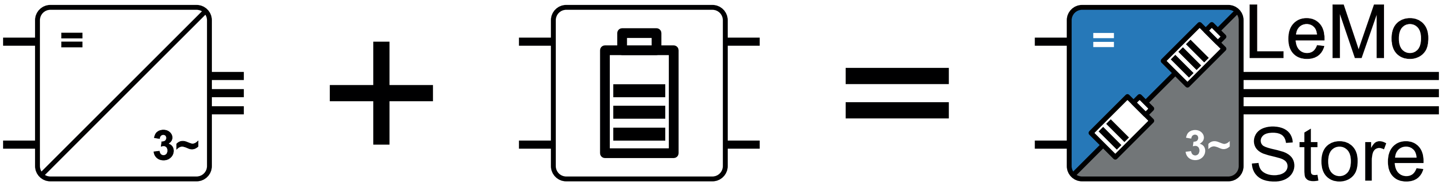
Karlsruhe Institute of Technology

Division III – Mechanical and Electrical Engineering

Institute of Electrical Engineering (ETI)

LeMoStore

Development of a modular energy storage system, that simultaneously serves as a converter for the power grid



Why Power Converters?

The power grid requires converters that convert direct current into alternating or three-phase current (and vice versa). This is relevant for photovoltaic systems, for example, which provide direct current. However, three-phase alternating current is common in the power grid, so the conversion is necessary.

Why Energy Storages?

Renewable energies in particular also have the characteristic that their electrical output is mostly weather-dependent. To compensate for this, energy storage systems are an important component in the power grid.

Why combine Converter and Energy Storage?

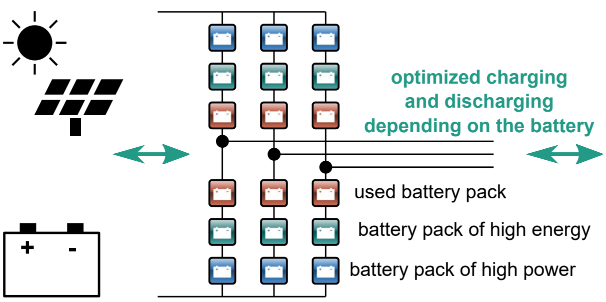
For LeMoStore, lithium-ion batteries are therefore integrated into the structure of a modular multilevel converter (MMC). The structure of the MMC allows high-quality three-phase AC power to be provided, as well as other DC sources and storage to be connected to the grid. The converter's power electronics can also be used for the optimal operation of the integrated energy storage devices. Thus, factors influencing aging as the number of cycles, longer-term charge levels, and maximum currents can be controlled.

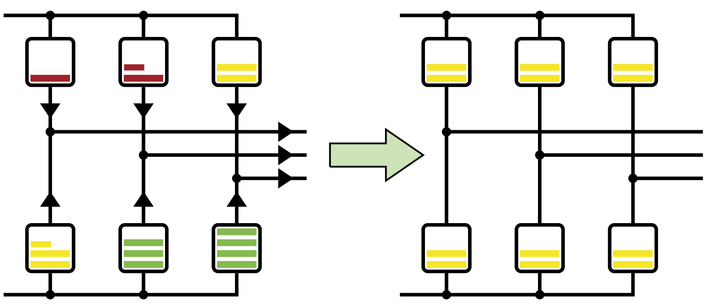
Second Life and Lifetime Optimization

To maximize the lifetime of the battery modules, LeMoStore uses novel modeling approaches to operate batteries of different types and ages in the MMC. By strategically dividing the charging and the discharging power, the maximum service life is achieved and even second-life battery cells can be charged and discharged according to their capability and thus achieve longer lifetimes. In addition, the optimized operation enables the reduction of the installed storage capacity and thus the realization of economically more favorable systems with identical characteristics. The developed system will be tested as a prototype in the Power-Hardware-in-the-Loop laboratory of the Energy Lab 2.0 at the KIT.

Flexibility

An MMC consists of six arms, two of which form a leg. In each of these arms, there may be battery modules in different states of charge that need to be charged and discharged with different amounts of energy during ongoing inverter operation. This is possible by regulating the power distribution between the arms in such a way that the desired charge levels are achieved. This can be used to equalize the charge levels of the batteries, as shown below. Modules within an arm can also be flexibly charged and discharged as long as the boundary conditions of operation are met.





Realization

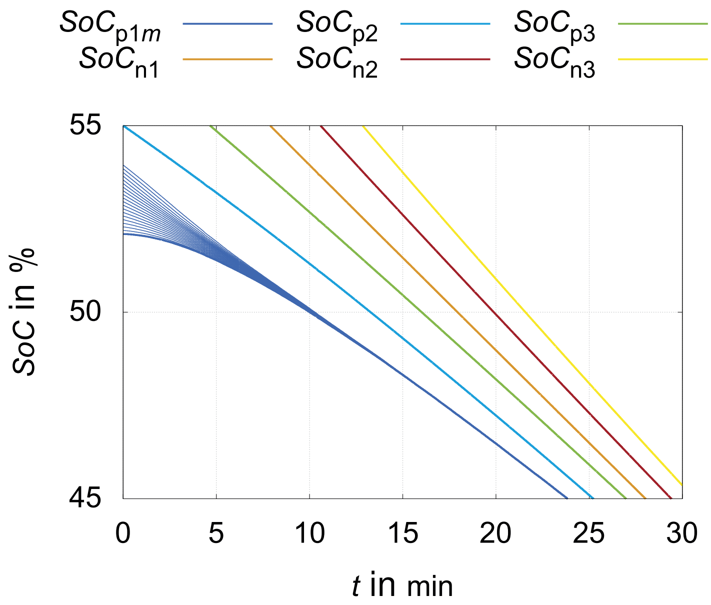
The MMC is designed for a voltage of 700 V on the DC side and is intended for connection to the three-phase low-voltage grid on the AC side. The demonstrator has a peak power of 100 kW, which is possible on both the AC and the DC side. Within the topology, 20 identical modules are used per arm, each consisting of a power electronic full bridge and a lithium-ion battery module. Operation is ensured by a hierarchical communication structure composed of a combination of FPGAs and microcontrollers.

Key Data Demonstrator

Power (max):	100 kW
Energy (max):	400 kWh
Battery Modules (max):	120 Pcs

Hardware-in-the-Loop

The design and the testing of a storage converter system is complex; Hardware-in-the-loop simplifies the development of the control and energy management. For this purpose, a simulation of the power electronics and the batteries is set up that is as close to reality as possible. It is equipped with the interfaces of the real system so that the platform of the controller and energy management can be connected. This is used in the project to analyze the behavior of the system before the demonstrator is put into operation and to simplify the development. The figure on this page shows such a hardware-in-the-loop evaluation. The charge levels of different battery modules over time can be seen. Both, within an arm and between the arms, it can be observed that the batteries' state of charge converge over time, which was the goal in this exemplary scenario.



One possible scenario: the charge levels of the batteries gradually equalize. The special feature: It also works if not all batteries are identical, as is the case with second-life batteries.

Project Partners

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