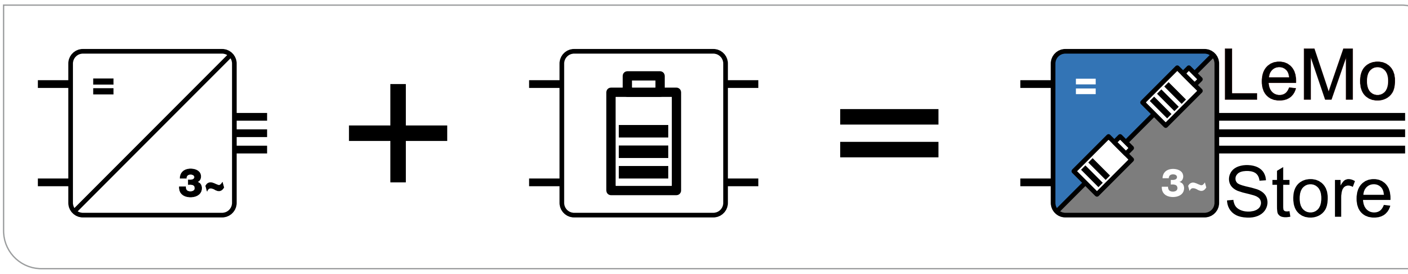
Karlsruhe Institute of Technology

Division III – Mechanical and Electrical Engineering

Institute of Electrical Engineering (ETI)

LeMoStore – Converter and Energy Storage

System with Integrated Battery Modules Combines Two Functions



Graphic: Lars Leister (ETI)

Converters are required in the power grid, for example to feed direct current from photovoltaic systems into the electrical power grid. At the same time, energy storage systems are required to compensate for power fluctuations from generators and consumers. The combination of both requirements in one system offers many advantages. The LeMoStore project (Lifetime Optimized Modular Energy Storage) focuses on optimizing the service life of batteries. In particular, this serves to enable the use of second-life batteries. The project is also investigating the benefits of the system for the power grid through so-called grid services.

Advantages of Combining Converter and Storage

A modular multi-level converter (MMC) consists of many identically constructed submodules. Each of these submodules contains power electronic switches (transistors). Their interaction enables an output voltage of high quality. Furthermore, a battery module is integrated into each submodule. The power electronics make it possible to individually influence ageing factors such as the number of cycles, long-term charge levels, and maximum currents for each battery module. This brings a decisive advantage: The battery modules do not have to be identical, allowing the use of second-life batteries.

Key Data for the Demonstrator

- Maximum Power 100 kW
- Maximum Energy 400 kWh
- Maximum No. of Battery Modules 120 units

Second Life and Service Life Optimization

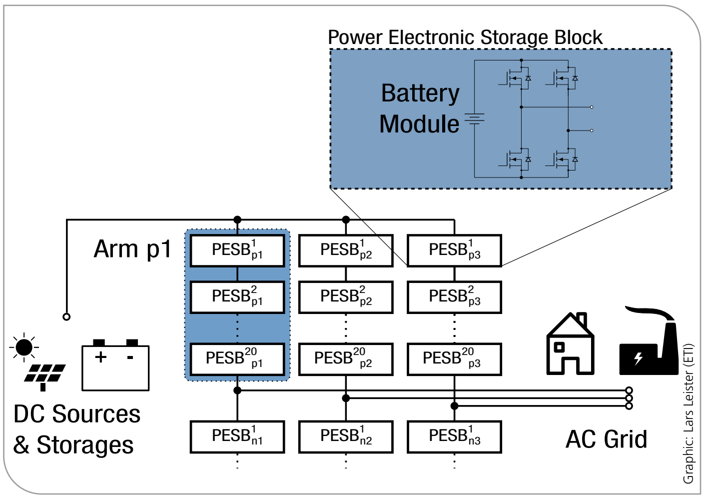
In order to be able to operate batteries of different types and ages in the MMC and to optimize their service life, the charging and discharging power is strategically distributed. This means, for example, that an older battery module is charged slower than a brand-new module of the same type. Optimized operation also makes it possible to reduce the installed storage capacity. This allows for the implementation of more cost-effective systems with identical properties.

Photo: Lars Leister (ETI)

Switch cabinet (arm) - one of the six arms of the overall system.

Goals and Key Factors

The system's main priority is to act as a converter to ensure that direct current can be converted to alternating current and vice versa at all times. This is possible regardless of the state of charge. In addition, the system provides various grid services which contribute to the stability of the power grid. Secondary to converter operation are the requirements of the energy management system. This system uses economic criteria to decide when energy should be stored and when the stored energy should be used or sold. These are the parameters according to which the required power is distributed to the individual battery modules. To this end, voltages, currents, and temperatures are continuously recorded during operation and used to derive parameters such as state of charge or ageing.



Structure of the modular multilevel converter with integrated batteries.

Technical Implementation

The LeMoStore MMC is designed for a DC voltage of 700 V and is intended for connection to the three-phase 230 V grid. The demonstrator can deliver a maximum output of 100 kW. Each arm of the topology uses 20 identical modules, each consisting of a full bridge (power electronic circuit) and a lithium-ion battery module with a maximum voltage of less than 60 V. The system is operated using a hierarchical communication structure.

Power Hardware-in-the-Loop Setup

Different operating scenarios are explored by testing the system in a realistic simulation environment. This allows to investigate different grid states and scenarios in a controllable environment. The power grid is simulated using emulators in KIT's Energy Lab.

Development Status and Commercialization

The LeMoStore project aims to address many different areas of application and scenarios. The components have therefore been selected to ensure that as much data as possible can be recorded and to allow a great deal of freedom in terms of control. In this respect, the aim of the project is not to commercialize the hardware setup presented, but rather to investigate and show what is necessary and what can perhaps be dispensed with. This helps to improve the economical operation of similar commercial systems and to make better use of the possibilities of such an approach through optimized operation.

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