Operation Strategies of Hybrid Energy Storages in Low-Voltage Distribution Grids with a High Degree of Decentralized and Fluctuating Generation

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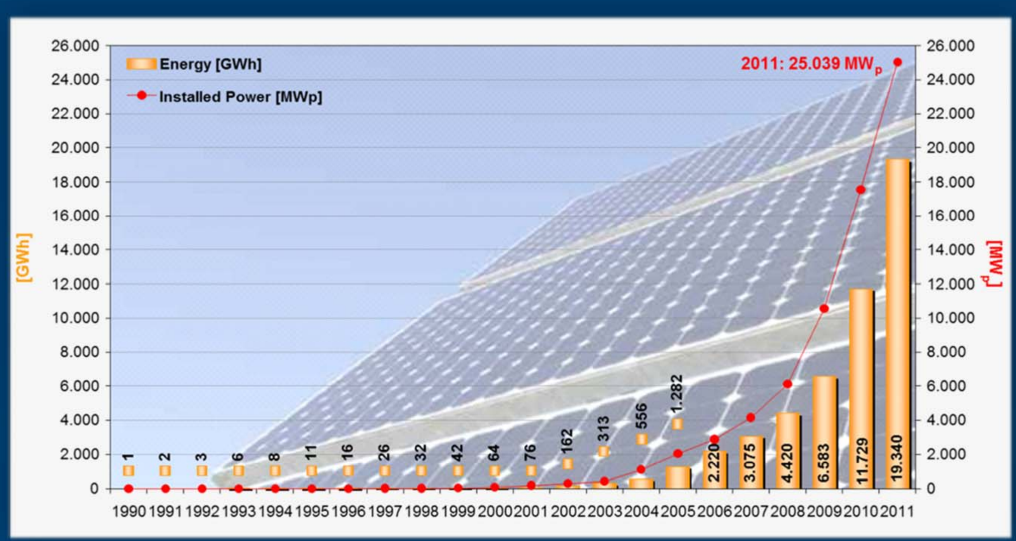
Motivation

- Further growing amount of decentralized power units: **30 GW_{peak}** of PV generation installed in Germany (August 2012)
- **Assumption:** Small-scale PV power plants will use all available roof areas in the future
- **Possibilities to increase feed-in:**
  - Grid reinforcement
  - Local energy storages

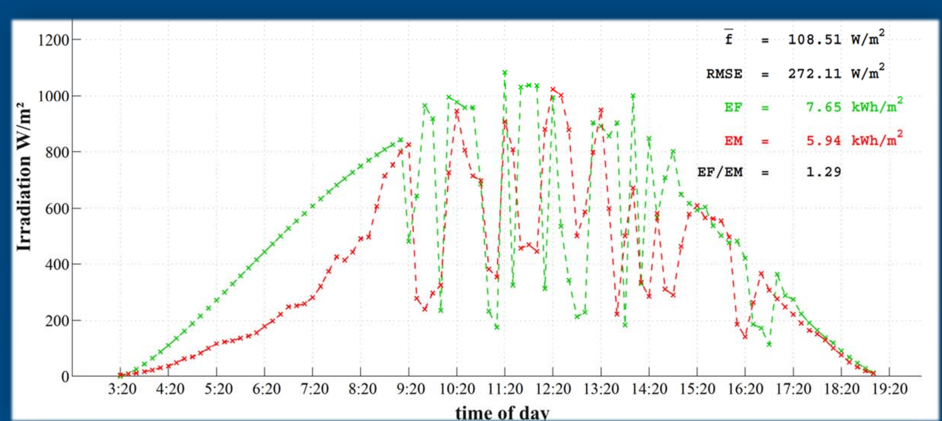


- **Optimization:** Detailed analysis of aging mechanisms of electrical storage system! Optimal usage of storage systems!

Irradiation and weather forecasts

The concept uses **optimization** and **forecast methods** to reduce the required storage capacity and to enhance the **self-consumption** of the local energy generation at the same time.

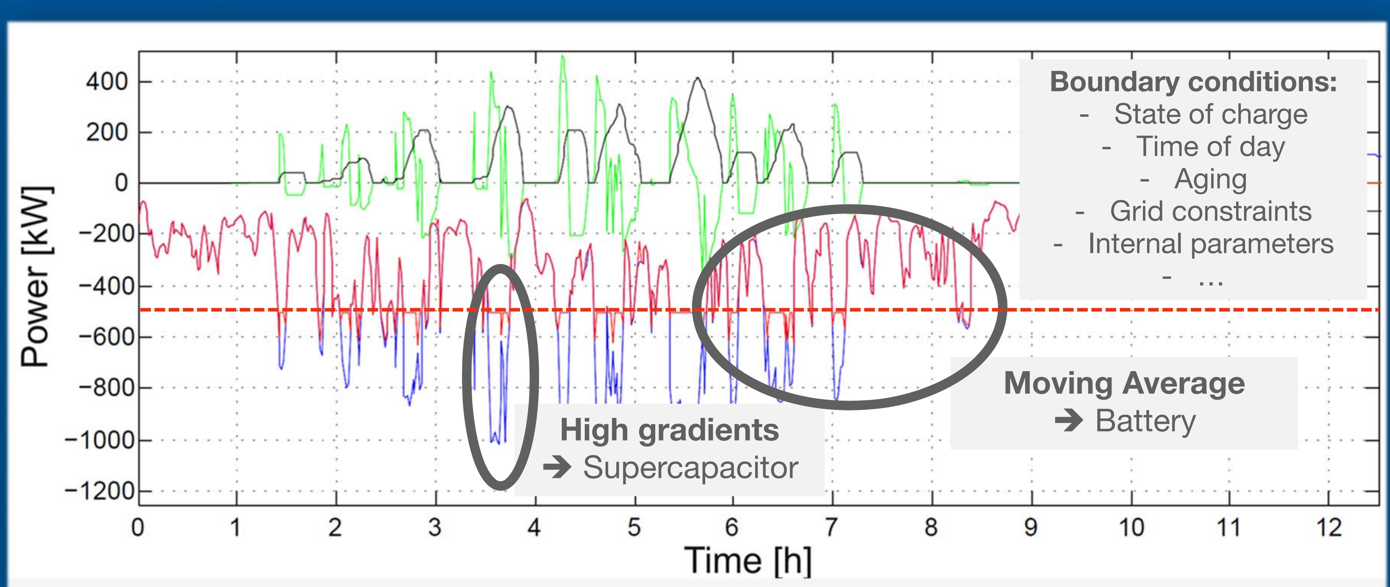
Therefore local **weather forecasts** will be interpreted as well as the feed-in of the decentralized photovoltaic plants of the past few days.



Forecast of the irradiation for an exemplary day in summer

Hybrid energy storage system

The hybrid storage system promises a possible approach by combining at least **two different storage technologies** with the aim to use the respective advantages and to compensate the disadvantages as possible. A coupling of **lead-acid batteries** for example with a **supercapacitor**, whose aging is less depending on the cyclization, could be a solution.

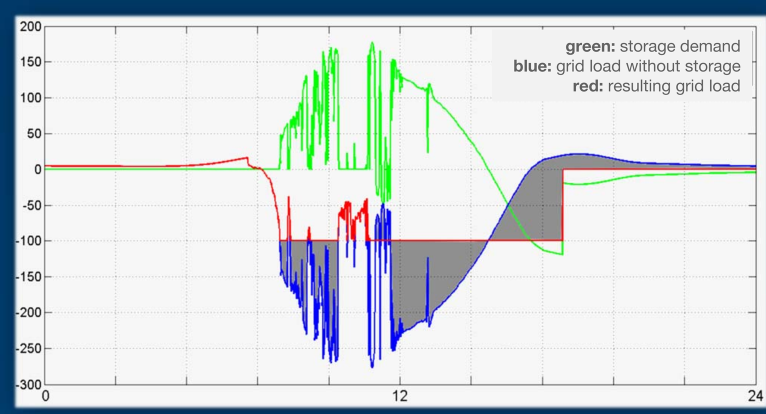


Exemplary course of a day of the hybrid energy storage system
(**blue:** grid loading without use of storage; **black:** power demand of the battery; **green:** power demand of the fast storage; **red:** resulting transformer loading)

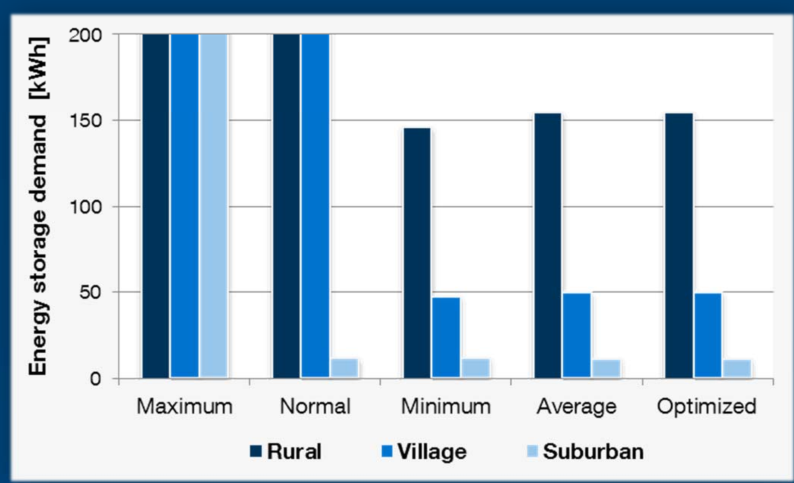
However, the **control strategy** of both storage technologies and the **design of the system** are essential for optimal usage.

Decentralized energy storages

Local energy storages, which save the surplus generation, can be an alternative to grid enforcement and can be essential for a stable and efficient energy network in the future. The minimal storage capacity necessary to fully integrate the possible photovoltaic plants is being calculated for several reference network.



Course of a day for the optimized usage of decentralized energy storages



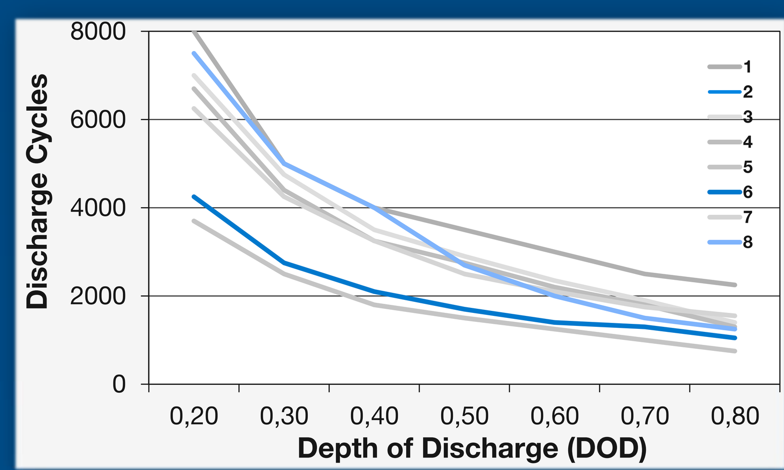
Minimal storage capacity of distributed energy storages necessary to fully integrate the photovoltaic plants

The rated power of the storage is best chosen in the range from **60 % to 85 %** of the respective **plant size**. Storage capacities for about **2.5 to 4 full load hours** are sufficient for the best exploitation. The local demand can mostly be covered with the help of the existing storage reserves.

Aging of electrical energy storage systems

Each cycle of a battery system causes irreversible losses in the usable storage capacity. Therefore a simulation model of the relevant aging phenomena (i.e. cycle lifetime and calendar lifetime) of energy storage systems was developed.

The **cycle lifetime** is mainly influenced by the charge and discharge cycles during operation. The **calendar lifetime** of a battery system is given by the processes, that occur without any operation of the system.

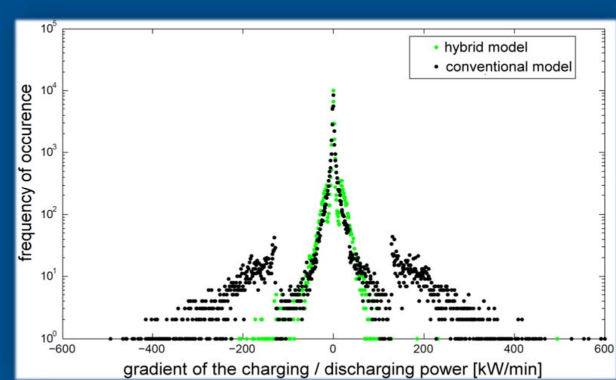


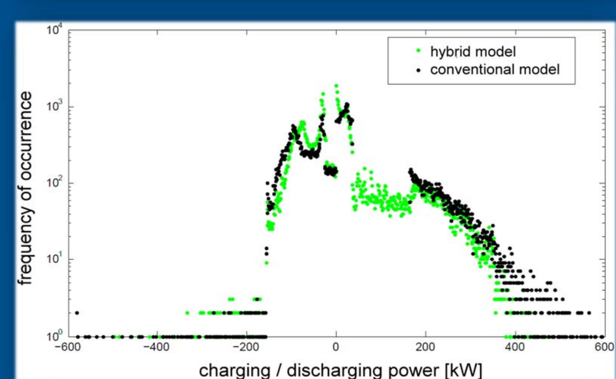
Results

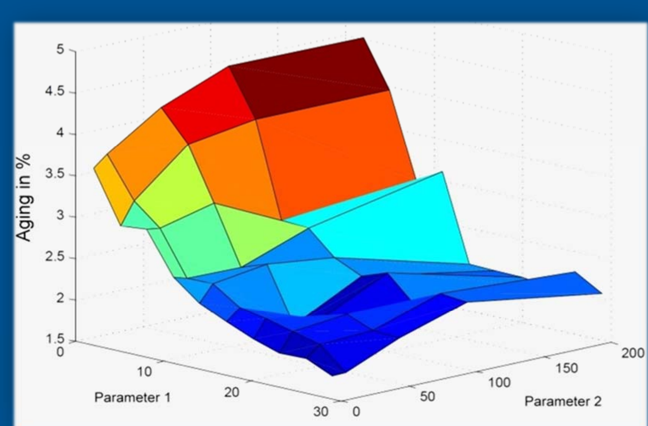
With the use of a fast double-layer capacitor high charging and discharging currents of the battery can be avoided. The chemical storage unit operates primarily for **low to medium currents**.

The average power demand of the battery can be **reduced by up to 20 %**.

The power gradients of the battery are **reduced to approx. 50 %** compared to the conventional model depending on the operating conditions.







In case of optimal control strategies the **aging and capacity loss** of the of hybrid energy storage system can be reduced significantly. Identification of the changes in the battery performance lead to more reliability and economic system operation.

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