A Hybrid Battery System

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Motivation

Battery Energy Storage Systems (BESSs) are considered as key elements for an effective integration of renewable energy sources in today's power systems. In grid applications the interest ranges from the home storage solutions in the kWh range for the integration of residential Photovoltaic (PV) plants, up to the MWh installations for the integration of large scale PV and wind power plants.

Despite a continuous reduction of the price of lithium ions battery cells, the part of a BESS in the final total system cost is still rather high and electrochemical battery systems do still have a high environmental impact. In Switzerland the cost to store one kWh of electric energy is similar to the generation cost of electricity from a PV source (about 0.15 CHF/kWh for network parity[1]). In addition a first study[2] on the life cycle of lithium ion batteries estimates a production of 12g of CO_2 for each kWh of energy stored.

Today the determination of the expected lifetime of BESS in real applications is still a challenge. In fact, the estimation of the health status of a battery is complex as it strongly depends on the operative conditions, especially temperature, charging method, current rate and profile. Beside this the introduction of new storage technologies doesn't facilitate the standardization of the testing procedures for the performances evaluation.

In this context the project HyperBat aims to reduce the cost and the environmental impact of electrochemical storages by means of a hybrid BESS, with the motivation to achieve a longer life time for the battery by supplying rather constant power in combination with a supercapacitor for power peaks. A lithium ion battery pack will be coupled with a supercapacitor pack by means of a power converter. The expected advantages in terms of power and energy density, life cycles, specific cost and efficiency are shown in Figure 1.

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1 A. Vezzini and M. Höckel, "Bald Netzpartität bei Batterien?," VSE Bulletin, no. 8/2016.

2 Y. Liang *et al.*, "Life cycle assessment of lithium-ion batteries for greenhouse gas emissions," *Resources, Conservation and Recycling*, vol. 117, pp. 285–293, Feb. 2017.

Challenges

Although the advantages of hybridization are not new in the industry, especially in the automotive field, the correct design of a hybrid system to attain the expected results is not trivial. The three main challenges related to the HyperBat research project are as follows:

1) Identify the “capability charts” showing the performances in terms of capacity, efficiency and life time in operation of the selected storage technologies. This information is not available in the manufacturer’s datasheet and ad hoc performances tests are required.
2) Define the best control strategies to split the energy and power demand between the two storage systems in order to guarantee that each single system operates in its best performance zone.
3) Build a simple and effective power conversion architecture to couple the different storage elements and to interface the entire system with the external terminals.

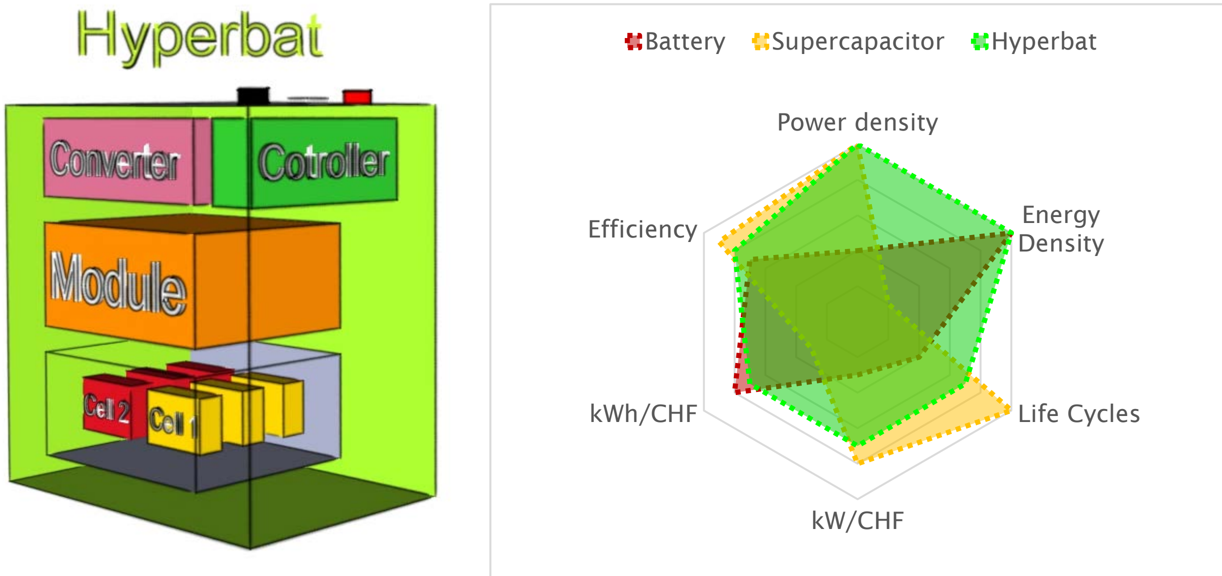

Figure 1, HyperBat concept (left) and expected advantages from the hybrid solution (right)

Activities at BFH-CSEM Energy Storage Research Centre

The laboratory infrastructure available at the BFH-CSEM Energy Storage Research Centre allows us to evaluate the real performances of the selected storage technologies: lithium nickel oxide battery and lithium capacitor. Ad hoc testing procedures have been developed to measure the energy and power density, efficiency and aging according to the real condition of use for the envisioned application. The procedure is application independent and let to map the real performance of the battery system as function of different current rates and current profiles of use. From these measurements it is possible to define the capability chart for the selected storage system, which allows the definition of the best control strategy of the hybrid system.

In parallel to the testing activity, a real prototype of 100 V nominal voltage, 3 kWh nominal energy and 9 kW of peak power is in phase of realization. The key element of the prototype is the power conversion unit: a unique power unit splitting the power flows between the two electrochemical storages and interfacing the entire system with the external terminals. The chosen conversion architecture guarantees any undesired current flow in case of short circuit at the external terminal as well as it protects all the elements from an excess of charge and discharge. All the control elements and communication interfaces with the storage elements are on board of the power converter without any additional control unit.

The same ad hoc test procedure adopted for the cell performance evaluation will be replicated on the integrated HyperBat prototype at the BFH-CSEM Energy Storage Research Centre in order to verify the expected advantages coming from the hybridization.

Partner

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The BFH-CSEM Energy Storage Research Centre unites several research groups of the Bern University of Applied Sciences (BFH) and the Photovoltaics Centre of the "Centre Suisse d'Electronique et de Microtechnique SA" (CSEM, Swiss Centre for Electronics and Microtechnology) in Neuenburg.

BFH-CSEM Energy Storage Research Center

Battery Research

A hybrid battery solution

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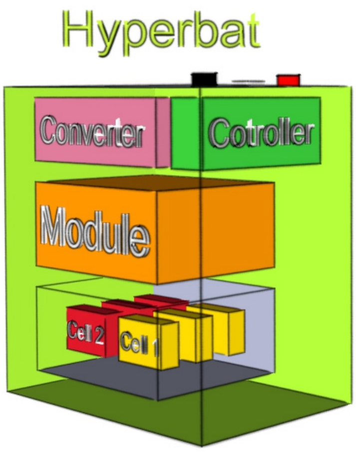
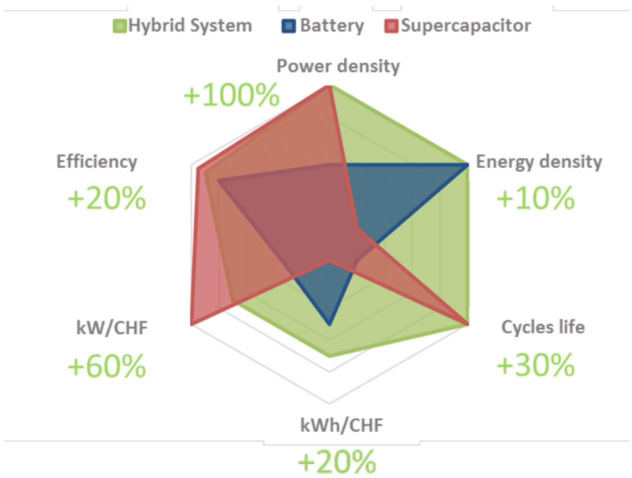
- Identify the performances in terms of capacity, efficiency and life time in operation of the both storage tech-nologies.
- Define the optimium control strategies to split the energy and power demand.
- Build a simple and effective power conversion architecture to couple the different elements.





The HyperBat concept (left) and the expected advantages of this hybrid solution (right)..

Based on the laboratory infrastructure available at the BFH-CSEM ESReC the performances of the selected storage technologies - lithium nickel oxide battery and lithium capacitor – are evaluated with suitable testing procedures. These measurements allow to define the capability chart for the selected storage systems, which is the basis for the definition of the control strategy for the hybrid system. A prototype with 100 V nominal voltage, 3 kWh nominal energy and 9 kW of peak power is currently in the phase of realization.

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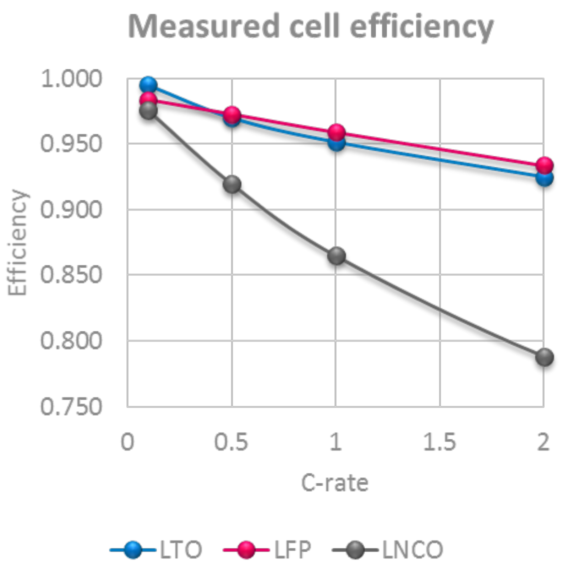
Battery Research

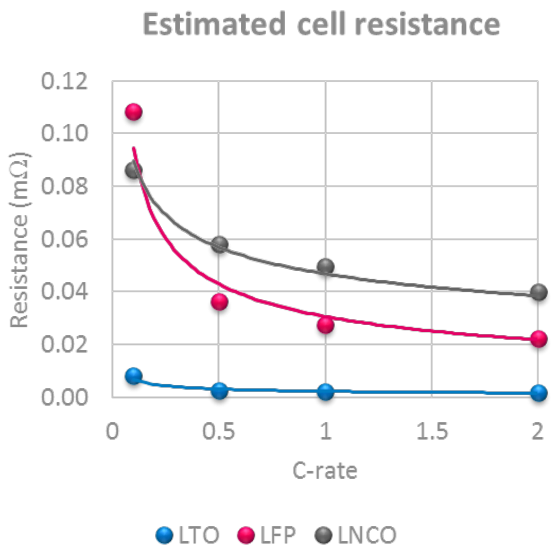
Application-independent protocol for predicting the efficiency of BESS

BFH-CSEM Energy Storage Research Center

The risk associated to the investment in Battery Energy Storage Systems (BESS) is high despite a continuous reduction of battery cell prices. Available testing procedures are not adequate to evaluate the performance of these systems in real operation. We developed a novel application independent procedure to predict the efficiency of lithium BESS from a single set of measurements and we have applied the novel procedure on three different lithium-ion cell technologies. We hereafter illustrate the accuracy of our procedure for the example of grid-connected BESS used for primary control reserve (PCR).

Our ad-hoc test procedure is able to evaluate the battery resistance as a function of the C-rate for a given temperature and it provides general "capability charts" based on which the efficiency can be evaluated under arbitrary operation profiles. The procedure consists of three main blocks: cell preparation, cell cycling at constant current for efficiency stabilization and efficiency computation.





Capability charts: measured cell efficiency (left) and derived cell resistance (right) at 25°C for three battery technologies: lithium titanate (LTO), lithium iron phosphate (LFP) and lithium nickel manganese cobalt oxide (LNCO).

In PCR the BESS is used to compensate grid frequency deviations by injection or absorption of active power. Since frequency deviations are stochastic, the current profile applied to the BESS in operation can be extremely variable. Results investigated for LNCO technology show that, if the regulation band is moderate and the SoC excursion is between 20% and 80%, the error between measurement and estimation is below 0.5%.

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