Karlsruhe Institute of Technology

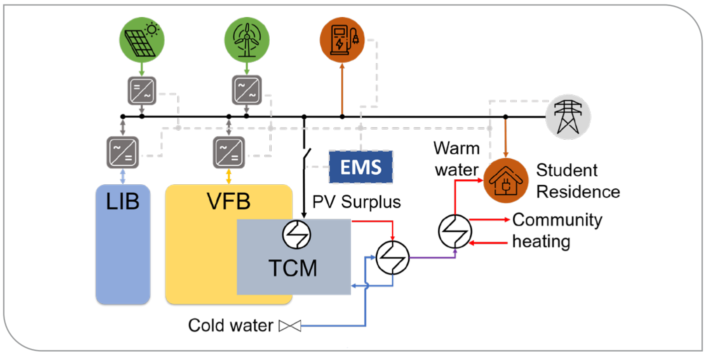
Hybrid Energy Storage System for Integration into Heat and Electricity Supply

BiFlow

Advantages of the redox-flow battery combined with those of the lithium-ion battery.

The project setup is located in a student residence in Bruchsal, Germany. BiFlow aims at a novel hybrid storage system that combines specific advantages of the redox-flow battery with those of the lithium-ion battery. The project is intended to prove the following innovation steps:

Hybrid EES in application: A vanadium redox-flow battery (VFB) and a lithium-ion battery (LIB) are installed to function as hybrid energy storage. With an optimal operation strategy, this system should reach higher efficiencies than its components individually could.
Increase of the overall efficiency of the VFB: The VFB shows lower round-trip efficiency (approx. 70 %) than the LIB. A new thermal coupling module is designed at KIT to recuperate most of the heat losses and to reach overall efficiencies of > 80 %.
Innovative dual usage of VFB as heat storage: The VFB's electrolyte is adapted to be stable at higher temperatures, thus allowing it to act as a heat storage medium. This opens up possibilities for cost- and space-efficient sector coupling in the context of the energy transition.



Real-life multi energy system setup. (KIT/Lakshimi Narayanan Palaniswamy)

VFB demonstrator

The VFB by 1st Flow Energy Solutions GmbH has a nominal power of 21 kW and a capacity of 120 kWh. Due to the VFB's modified electrolyte composition, it operates at an expanded temperature range of 10 – 50 °C.

Each electrolyte tank is equipped with a 35 kW heat exchanger, transferring excess heat from the VFB to the warm water supply of the building.

Features:

- Cycle life > 20 000 cycles
- Product lifetime > 20 years
- Recyclable electrolyte and battery components
- Neither flammable nor explosive
- Independent power to capacity ratio
- No degradation of capacity during operational lifetime

Vanadium redox-flow battery with insulation. (KIT/Felix Schofer)

Adaptation of electrolyte for heat storage

In order to adapt the VFB electrolyte for electrochemical and thermal use in the range of 10 °C – 50 °C, the relationship between electrolyte formulation and the operating characteristics at elevated temperature was investigated by Fraunhofer Institute for Chemical Technology ICT.

Challenge: Standard VFB electrolyte's operating temperature range is 0 °C – 35 °C. Vanadium tends to condense irreversibly to vanadium pentoxide at around 40 °C. The following solutions are investigated:

1. Use of additives, which stabilize pentavalent vanadium solutions and prevent flocculation of vanadium oxides
2. Use of mixtures with sulfuric acid, adjustment of vanadium to sulfuric acid concentrations

Approach: By diluting the electrolyte with acid, the thermal stability of the electrolyte can be enhanced at the expenses of battery capacity. A compromise between stability and capacity is investigated.

Thermal Coupling Module

An innovative Thermal Coupling Module (TCM) is used to transfer thermal energy to and from the VFB: The heat is extracted from the electrolyte tanks via the aforementioned heat exchangers in the tanks, each with a nominal power of 35 kW at a ΔT of 20 °C. A third heat exchanger with a nominal power of 75 kW at a ΔT of 20 °C transfers heat from the TCM to the hot water supply of the building. In addition to the heat exchangers, an electric heating element can be used to heat up the VFB tanks or the hot water supply using excess photovoltaic power. By using valves to direct the flow of thermal energy, the TCM can be operated in three different modes:

- Heating up one or both electrolyte tanks using the heating element
- Transferring heat to the hot water supply using the heating element
- Transferring heat from one or both electrolyte tanks to the hot water supply

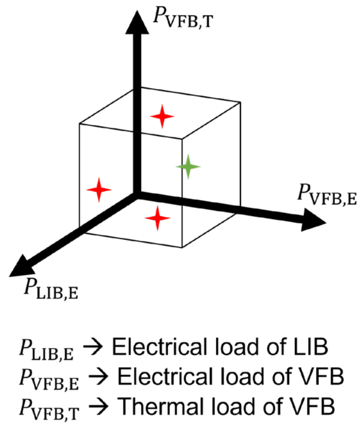
Thermal coupling module with heating element and heat exchanger for hot water supply. (KIT/Felix Schofer)

Real-time optimization of setup

The whole setup is controlled through a centralized energy management system (EMS) where the operations take place at 250 ms intervals. The EMS aims at solving a multi-objective optimization problem with the following goals:

- Improve the economic performance of the VFB and the LIB
- Reduce operation losses and standby consumption
- Maximize waste heat utilization of the VFB
- Reduce aging of the VFB and the LIB
- Improve the setup self-sufficiency in terms of electricity and hot water requirement

Challenge: Operational efficiency of the VFB is not only dependent on its electrical but also its thermal state. The unique dual usage of VFB creates a new three-dimensional optimization problem statement: The EMS must find the optimum operation point in the operation volume, at which the hybrid storage system is not only optimized in electrical terms, but the VFB is also optimized in thermal terms as visualized below.



Three-dimensional optimization problem.
(KIT/Lakshimi Narayanan Palaniswamy)

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