Karlsruhe Institute of Technology

ENERGY LAB 2.0

Together with other energy storage systems, redox-flow systems play a key role in stabilizing the energy supply.

The Redox-Flow-Storage

Large storage solutions are indispensable for the energy supply of the future. While lithium-ion batteries (LIB) have been tremendously successful for all kinds of portable devices and become state of the art for electromobility, it may not be sufficient when it comes to large energy storage due to limited lifetime and resources. Redox-flow batteries (RFB) are very suitable for large stationary energy storage applications based on very good lifetime expectations, good recyclability, safety and fewer scarce resources are used. Despite these advantages, RFB is clearly inferior to LIB in efficiency and system complexity.
It should be mentioned, however, that the LIB has a significantly longer development period than the RFB and there is still significant potential for optimization here. One approach is to analyze the efficiency of the individual components and the overall system at different operating points in order to uncover operating points with optimal efficiency. The operating behaviour of the RFB is contrasted with that of the LIB to reveal the strengths and weaknesses of the technologies and to develop an optimal operating strategy for hybrid operation of both storage systems.

- Chemical composition of the electrolyte:
  Anolyte (positive): Vanadium-oxide-sulfate + sulfuric acid
  Katolyte (negative): Divanadium trisulfate + sulfuric acid
- Electrolyte volume: 53 m³
- Energy: 860 kWh
- Energy density: 16.2 Wh/l
- Cells per Stack: 27
- Voltage range Stack (27-43) V
- DC-Voltage of power unit: (700 ±50) V
- Number of Stacks and DC-converters: 80
- AC-efficiency at the grid connection point: 68%
- Active power control range: ±200 kW
- Reactive power control range: ±200 kvar
  Energy demand of the auxiliary circuits: < 7%

Front view of the Redox-Flow-Storage system. The upper container contains the stacks. The lower container contains the tanks for the electrolytes, which supply the stacks via a pump system.

Headerfoto: A.Bramsiepe, KIT

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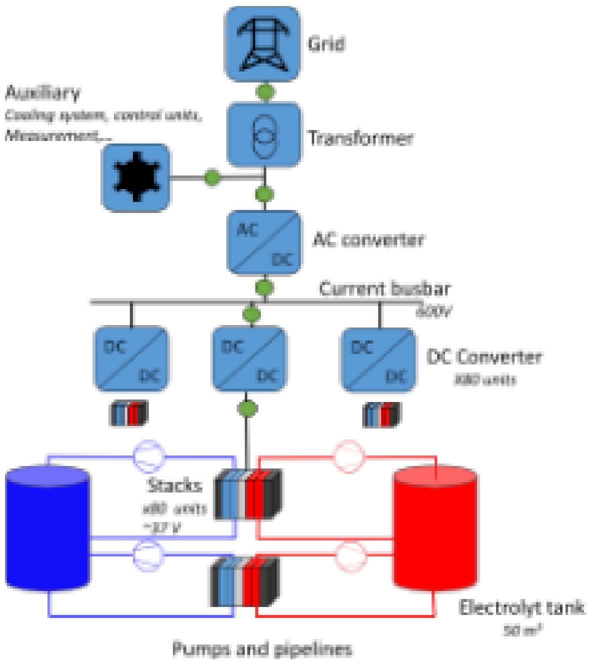

Plan of the entire Redox-Flow-Storage system. From bottom to top: The tank, the pump system and the stacks from which DC voltage is stepped up to approx. 600 V. The current is collected on the high-voltage bus and converted into AC in order to feed it into the grid.
The green dots mark the measuring points for operational analysis and efficiency calculation.

Fundamentals

In redox-flow batteries, charging and discharging takes place through redox reactions of the electrolytes used. There are an anolyte and a catholyte, which have more or less the same role as cathode and anode in other battery technologies, like lithium-ion batteries.
However, the actual electrochemical conversion takes place in the so-called "stacks". For this purpose, several cells are serially connected to form a bipolar stack. Electrolytes flow through them from the tanks below via a pump system. Vanadium redox-flow batteries use vanadium in four oxidation stages.
Moreover, the stacks are connected to the necessary power electronics to collect the power of the individual stacks and transform it from direct current (DC) to three-phase alternating current (AC) for the public grid.

Research Focus and Approach

To be able to evaluate the performance of a storage system and compare it with other systems, measuring points are installed at different components. These can then be specifically characterized. While most losses can be calculated via power differences, losses in electrochemical storage systems, however, can only be calculated by balancing the amount of energy stored and released. For this purpose, it must be ensured that the respective energy storage device, at the end of the balancing period, is in the same state as at the beginning. Thus, it is particularly necessary that it has the same state of charge and the same temperature.

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