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ENERGY LAB 2.0

Together with other Energy Storage Systems, Redox-flow Systems Play a Key Role in Stabilizing Energy Supply.

The Redox-flow Storage System

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, they may not be sufficient when it comes to large energy storage due to their limited lifetime and scarcity of resources needed. Redox-flow batteries (RFB) are very suitable for large stationary energy storage applications thanks to their very good lifetime expectations, good recyclability, safety, and their smaller need for resources. Despite these advantages, RFB are clearly inferior to LIB in efficiency and system complexity.
It should be mentioned, however, that LIB development takes much longer than that of 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 behaviours of RFB and LIB are compared to identify 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
  Catholyte (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 accomodates the tanks for the electrolytes that are supplied to the stacks via a pump system.

Photos: A. Bramsiepe, KIT

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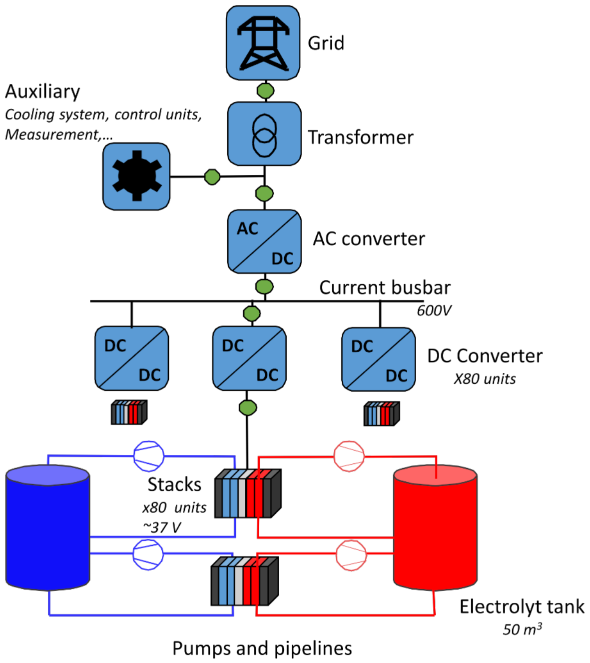

Plan of the entire redox-flow storage system
From bottom to top:
The tank, the pump system, and the stacks from which DC voltage is stepped up to approx. 600 V. The current is collected on the high-voltage bus and converted into AC to feed it into the grid. The green dots mark the measuring points for 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 play 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 and are pumped up from the tanks below by 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 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 can only be calculated by balancing the amounts of energy stored and released. For this purpose, it must be ensured that the state of the energy storage device at the end of the balancing period corresponds to that at the beginning. In particular, the states of charge and temperatures have to be identical.

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