Overview of Redox flow technologies, challenges, and opportunities

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The crucial evolution of the energy mix depends in particular on the development of renewable energies. The two main alternatives to fossil fuels are photovoltaic energy and wind energy, whose intermittent nature requires them to be combined with a stationary energy storage system. Redox flow batteries (RFBs) are currently well suited to this type of application, particularly for long-term energy storage (more than 8 hours). Their principle is based on the circulation of two electrolytes, the posolyte and the negolyte, stored in tanks external to the electrochemical cell. One of the advantages of this configuration is that it allows the power and capacity of the system to be adjusted separately according to actual needs.

In the 1970s, following work carried out by NASA, various projects focused on the use of dissolved inorganic electroactive species, as illustrated by all-vanadium technology (VRFB) and hybrid technologies using zinc at the negative electrode (Zn/bromine or Zn/hydrogen technologies). Although the vanadium system is increasingly developed industrially, it could suffer from defects such as limited solubility/stability (resulting in energy densities of around 33 Wh/L), the passage of soluble species through the membrane, high cost, and the criticality of vanadium. Research avenues have diversified significantly since the 2010s, primarily through the study of aqueous redox flow batteries with organic electroactive centers. Numerous studies have also emerged on non-aqueous electrolytes (particularly acetonitrile and carbonate mixtures) in an attempt to increase energy density by expanding the range of electroactivity. More recently, the use of dissolved redox mediators combined with solid electroactive materials immobilized in reservoirs has been proposed (“redox targeting”).

In this presentation, we will review the systems aspects and recent advances in the various approaches, and underline the limitations and opportunities with these systems.