An alternative stack topology for vanadium redox flow battery

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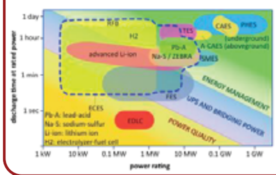
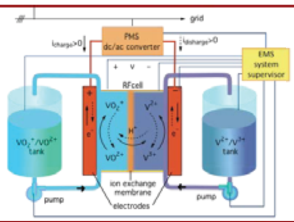
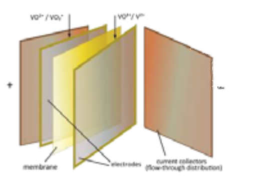
This work was done within the MAESTRA strategic project of the University of Padua that aims at developing state-of-the-art technologies for Vanadium Redox Flow Batteries (VRFBs) The experimental program is developed on a fully-monitored industrial size test facility and is supported by extensive numerical analyses. In this framework, two alternative stack topology have been numerically compared: conventional **series stack** and alternative **parallel stack**. Two cell fluid architectures have also been compared: the **channelled plate** (current collector), and the **flat plate**.

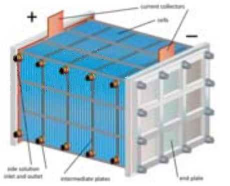
Vanadium redox flow batteries

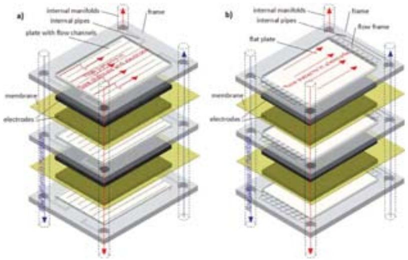


- Power/energy independent sizing
- High cycling life (>20.000 cycles)
- High round trip efficiency (>75%)



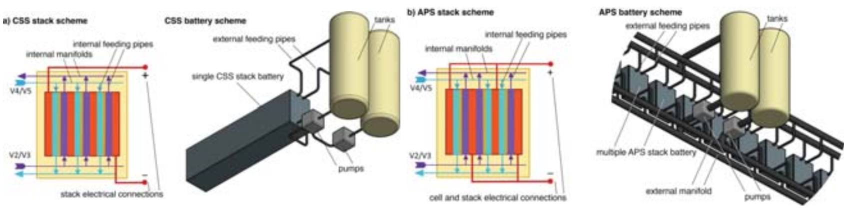




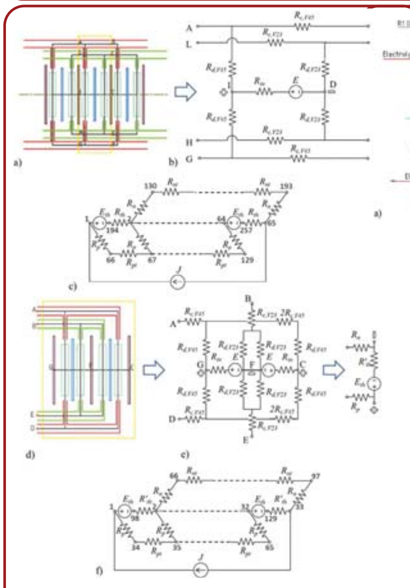


Cell configuration:
plates (current collectors)
graphite porous electrodes
membrane

Two alternative fluid distributions
a) channelled plate (interdigitated geometry)
b) flat plate.



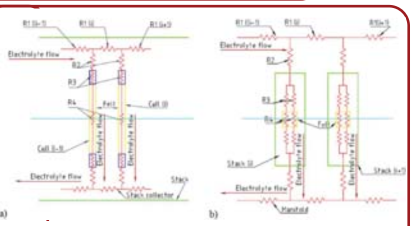
Stack topologies: a) conventional **series** stack (CSS); b) alternative **parallel** stack (APS).



Equivalent networks for shunt current computation

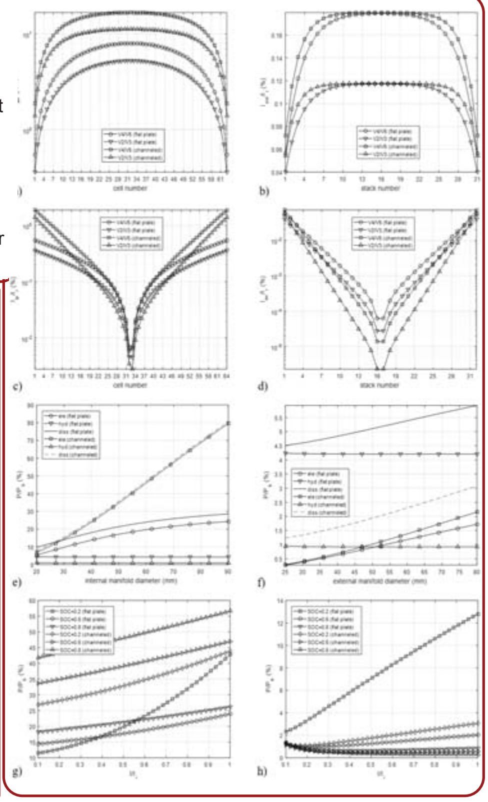
a) CSS piping; b) CCS network;
c) CSS network after symmetry reduction.

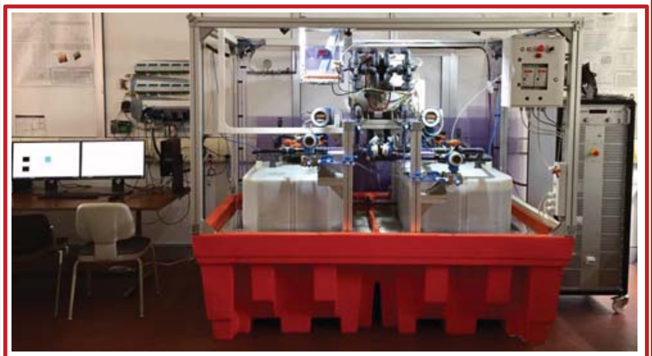
d) APS piping; e) APS network of two cells with piping;
f) APS network after symmetry reduction.



Segments of the hydraulic circuits:
a) CSS; b) APS.

CSS
shunt currents: a) internal manifolds c) internal piping, total power losses: e) for different external manifold diameters, g) at different currents and SOC.
APS
shunt currents: b) internal manifolds and d) internal pipes power losses: f) for different internal manifold diameters, h) for different currents and SOC.





4-kW / 24-kWh VRFB test facility
40-cell stack and two 500 L tanks, two flow pumps powered by inverter-controlled brushless motors, a bidirectional power management system, a Labview-based system supervisor, multi-voltage, current, pressure, flow and temperature measurements, EIS.

A performance model of the cell, a model for shunt currents and a model for hydraulic losses have been developed and assembled, for both CCS and APS. Comparative analyses between APS and CSS for 4.5-kW batteries (residential users) has been carries out. APS can provide markedly lower losses than CSS, and thus an efficiency, reasonably higher by 10%, allowing to achieve an overall battery efficiency around 85%. APS are more cumbersome on the small scale, but the difference vanishes in the case of 10^2-kW and MW systems. The implementation of the APS into our test facility will be taken into account in a future development program. Early program on the present test facility includes SOC (state of charge) analyses to maximize energy extraction, analysis of the active control of electrolyte flow to minimize losses, temperature analysis to avoid precipitation, aging analyses.

References

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