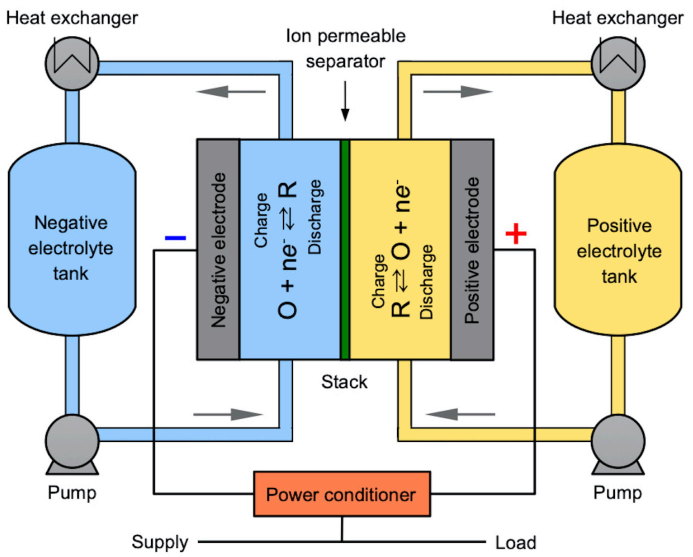
Advances in electrochemical reactors: Redox flow batteries for energy storage

Dr Luis Fernando Arenas

lfam1c17@soton.ac.uk

Visiting Academic, University of Southampton, UK.

Present address: Saltillo, Mexico.



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Host: Professor Thomas Turek

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Meeting Humboldt-Club Mitte Nord, 23 June 2021

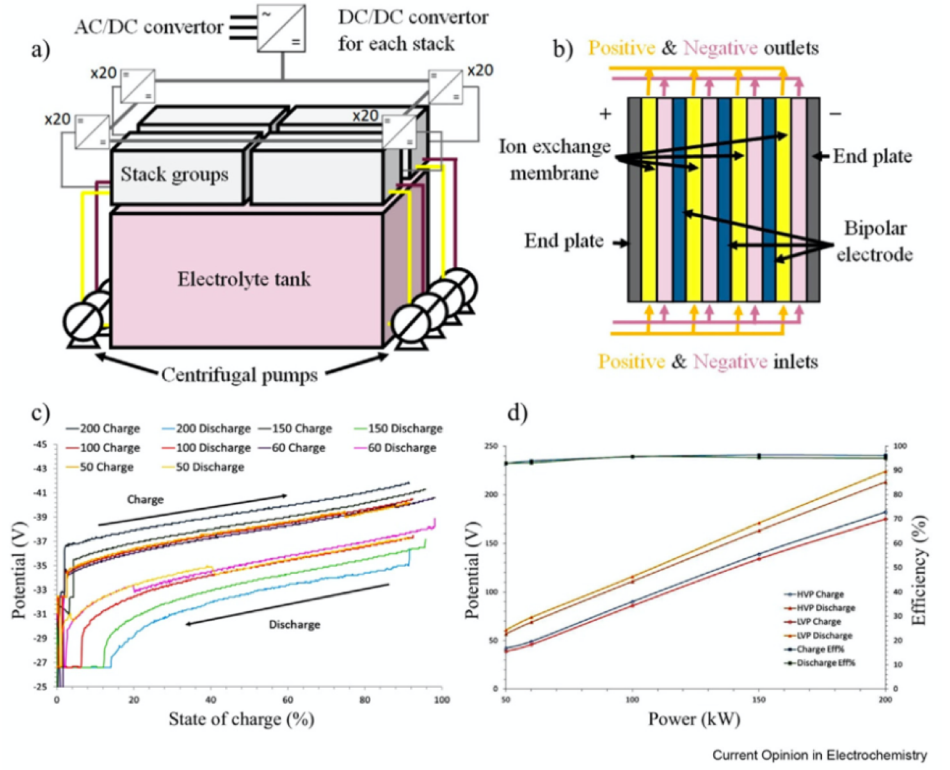
Content

- Introduction
- Importance of energy storage
- What are redox flow batteries?
- Advantages and benefits
- Commercial devices
- Conclusion

Importance of energy storage

Panorama:

- Urgent need of de-carbonisation.
- Increase in demand: electronics, electrical cars, etc.
- Increasing availability and lower cost of renewable sources.
- Need to manage intermittence, reduce curtailment.
- Lack of adaptability of the electrical grid.



(a) A four-stack 200 kW/400 kW h vanadium RFB along pump and power conditioner. **(b)** Arrangement of bipolar electrodes and electrolyte flow. **(c)** Total stack potential over a range of constant power charge–discharge values. **(d)** DC/DC convertor potential losses and efficiency at 'high voltage' (HVP) and 'low voltage' (LVP) modes. Adapted with permission from Bryans et al. [75], Characterisation of a 200 kW/400 kW h vanadium redox flow battery, Batteries 4:54. Open access (2018) CC BY 4.0 licence.

Benefits of energy storage:

- Gives flexibility to the grid.
- Controls demand peaks.
- Increased supply security.
- Enhanced efficiency.
- Long-term cost savings.

L.F. Arenas, C. Ponce de León, F.C. Walsh. **Engineering aspects of the design, construction and performance of redox flow batteries.** (2017) *J. Energy Storage, 11:119.*

Utility-scale energy storage technologies

Global storage to 12x by 2030. Patrik Larsson & Philip Bo̎rjesson from Bloomberg data (2017).

Air compression

Flow batteries

Pumped hydro

Super-capacitors

Lithium ion

Fly-wheels

To be defined in the next 10 years

Location

Capacity

Response time

Safety

Considerations*:

- Capital cost
- Cost per cycle
- Maintenance cost
- Efficiency
- Maturity/reliability
- Self-discharge

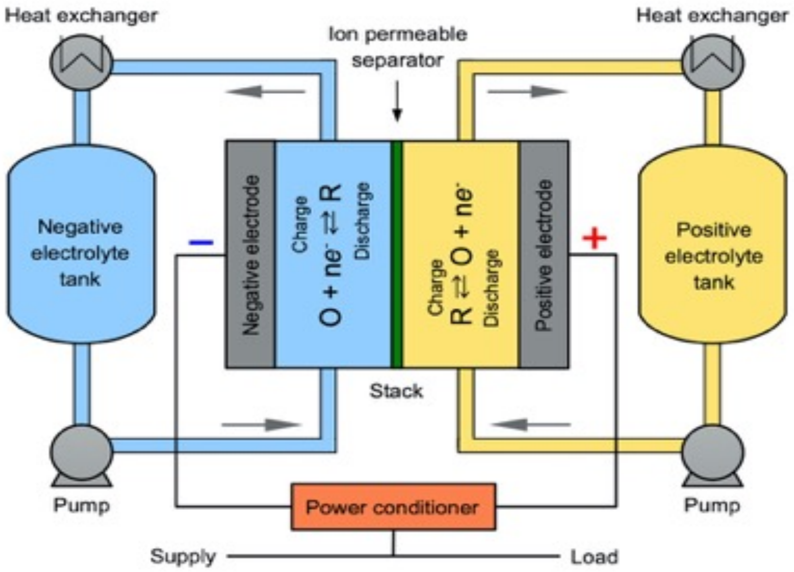
What are redox flow batteries?

Characteristics:

- Reversible electrochemical reactors.
- Energy stored in soluble redox couples.
- Electrolytes in constant recirculation.
- Capacity = volume of liquid in tanks.

Components:

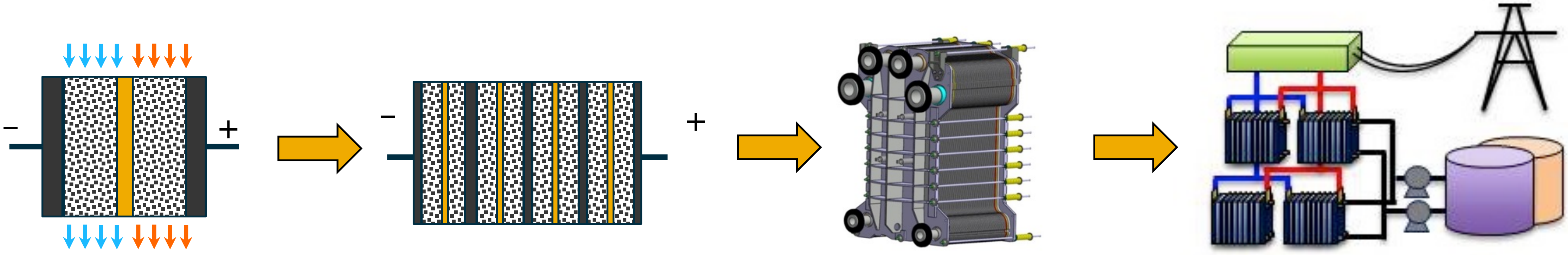
- *Stacks (of cells, membrane-divided)*
- Pumps, tanks, teat exchangers.
- Power/battery management system.



Redox flow battery

Benefits:

- In general, power rating is independent from capacity.
- Modular
- Scalable.



Flow cell | 'Stack' of unit cells | Filter-press type reactor | Flow battery system

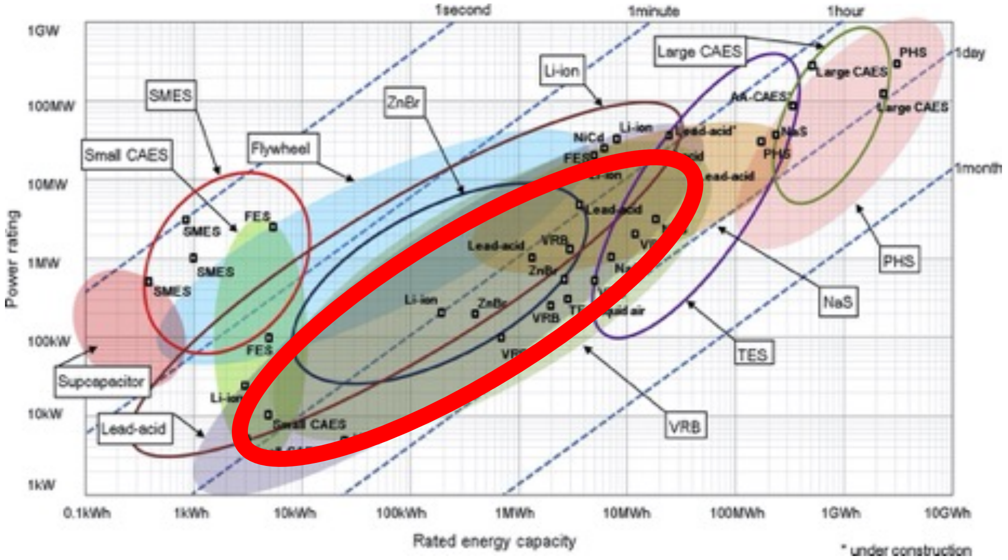
L.F. Arenas et al. **Engineering aspects of the design, construction and performance of modular redox flow batteries for energy storage.** (2017) *J. Energy Storage*, 11:119.

What are redox flow batteries?

Applications:

- Stationary energy storage
- Integration of renewables.
- Reduction of curtailment.
- Long (hours) duration energy storage.
- Isolated/remote microgrids.
- Telecomm tower sites.

Ragone plot



Luo X et al. (2015) Applied Energy 137: 511-536. Open Access

Environmental benefits (dependent on type of RFB):

- Lower-risk supply chains.
- Recoverability and recyclability.
- Possibly very abundant substances.

e.g. bromine, zinc, iron, vanadium minerals

Advantages (vs. Li-ion):

- Service mode can adapt to demand.
- Ample response time range.
- Simple electrical/thermal control.

Safety (vs. Li-ion):

- No thermal runaway.
- Only **two** electrolytes to control.

Whitehead et al. *J Power Sources*. 2017;351:1-7.

L.F. Arenas, C. Ponce de León, F.C. Walsh. **Engineering aspects of the design, construction and performance of redox flow batteries.** (2017) *J. Energy Storage, 11:119.*

Commercial RFBS

Zinc-Bromine (1.25 V)

- e.g., RedFlow (Australia)
- Mature technology.
- Zinc plating (limited capacity)
- Low-cost substances.

Vanadium-Vanadium (1.82 V)

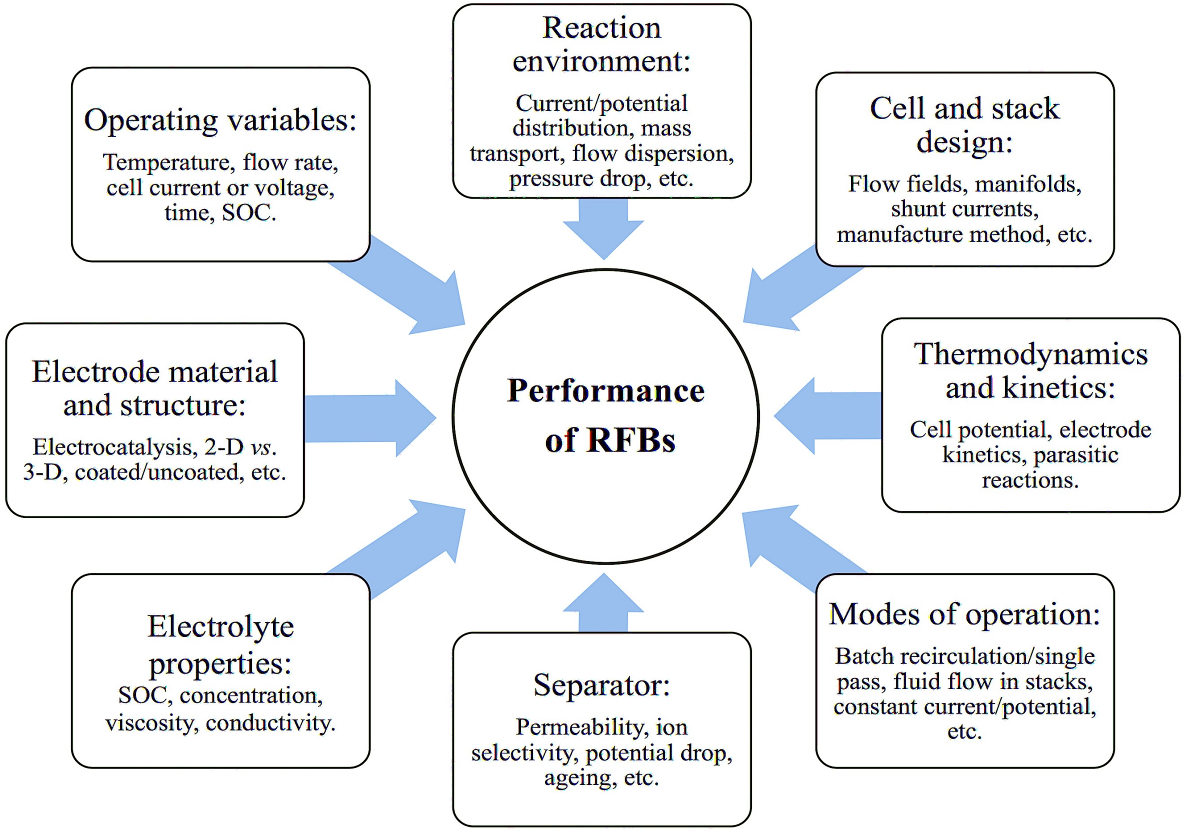
- e.g., Sumitomo (Japan)
- High degree of development.
- Almost cost-competitive.
- Copes with capacity loss.
- Electrolyte is recoverable.

Organic Redox Molecules (~1 V)

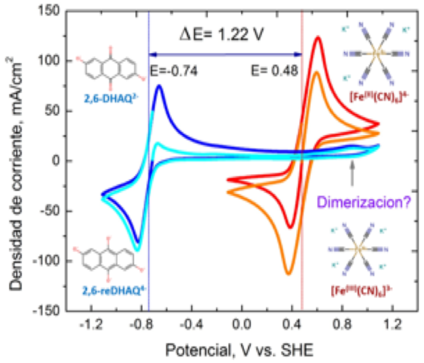
- e.g., Jena Batteries (Germany)
- Availability of materials.
- No risk supply chain.
- No mining impact.
- Still in development.

Research on RFBs

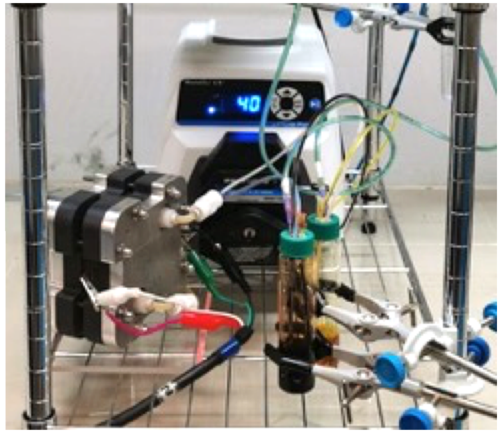
Electrochemical engineering aspects



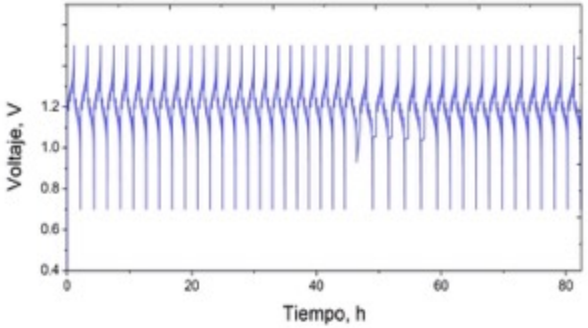
New chemistries organics



Evaluation of performance



Charge-discharge



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To keep in mind:

- RFBs are a viable alternative for energy storage.
- Important developments can be expected.
- Technical and environmental benefits are possible (chemistry dependent)

Recent papers:


Critical Review—The Versatile Plane Parallel Electrode Geometry: An Illustrated Review


Three-dimensional porous metal electrodes: Fabrication, characterisation and use


Redox flow batteries for energy storage: their promise, achievements and challenges

- The versatile plane parallel electrode geometry: An illustrated review
- Redox flow batteries for energy storage: Their promise, achievements and challenges.
- Three-dimensional porous metal electrodes.

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