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- Presentation Title: Voltage Transforming Batteries as a New Class of Advanced Power Transformers
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- Organization(s): Idaho National Laboratory

Bjorn Vaagensmith, PhD
Idaho National Laboratory

Voltage Transforming Batteries as a New Class of Advanced Power Transformers (VTB)

DOE OE TRAC Peer Review 2026

U.S. DEPARTMENT of ENERGY

Battelle Energy Alliance manages INL for the
U.S. Department of Energy's Office of Nuclear Energy

Idaho National Laboratory

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- INL Laboratory Program Manager (LPM), Relationship Manager (RM)
  - Jake P. Gentle (Jake.Gentle@inl.gov)

Project overview

Project description:

- Develop the world's first chemical-based transformer with built in energy storage for improved grid resilience and reliability
- Reduce supply chain dependence on traditional copper-coil-based transformers

Alignment/supports strategic pathway:

- Stabilize the grid to address the immediate, acute conditions that strain reliability
  - A Voltage Transforming Battery (VTB) can provide traditional benefits of energy storage devices while also providing the function of a transformer
- Grow the grid by enabling a small-footprint update to grid infrastructure with transformer capabilities
  - Faster supply chain
  - Buffer against data centers
  - Mid-term solution for infrastructure upgrades

Period of Performance:
10/01/2025 – 09/30/2026

Award Amount: $300k
In-kind materials provided by Storion Energy

Prime Awardee:
Idaho National Laboratory

Partners:
Invinity, Storion Energy

Technology Area:
Advanced Transformers

Project overview

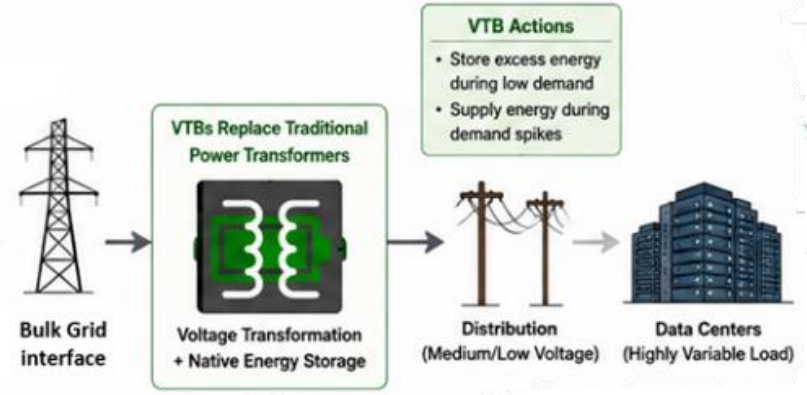
Industry Impact:

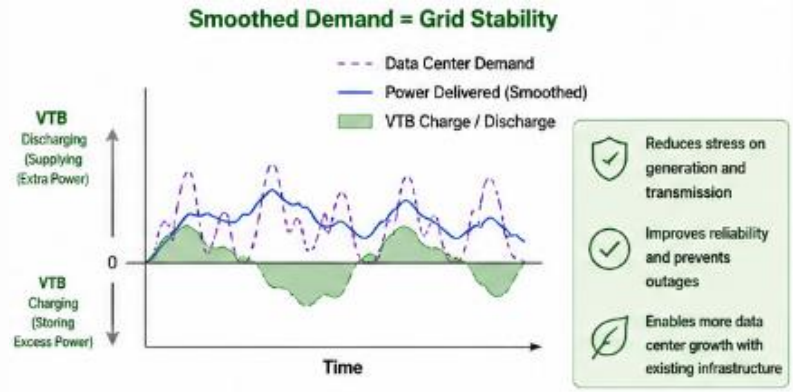
- Provide a buffer for the variable energy demand from data centers and other large loads
- Enhance grid reliability by balancing demand changes

Major Accomplishments:

- VTB setup completed in lab
- Laboratory testing
- Input from National Association of Regulatory Utility Commissioners (NARUC), National Association of State Energy Officials (NASEO), Utilities, and grid technology advocacy coalitions







Problem statement: *VTBs*



Power flow analysis of potential overloaded lines due to anticipated large loads

- There are identifiable nodes in large grid architectures where the grid capacity is, or soon will be, frequently stretched to unsustainable levels
  - With aging and overcrowded infrastructure, there is little room for growth
- This project proposes a new class of devices that perform the function of conventional power transformers while simultaneously providing energy storage
- Strategically placed VTBs will help alleviate such problematic zones that would otherwise be weak links in the grid service
  - This provides a small footprint, forward-thinking solution

Technical approach / innovations

- **Figure 1a:** Leverage multiple flow batteries jointly connected to a single electrolyte storage tank
- **Figure 1b:** Each flow battery stack can operate at a different voltages
- **Figure 2:** Additional voltage adjustments can be made through power electronic interfaces

First ever bulk storage configuration that allows for simultaneous charging and discharging

- Provide energy storage, stability, voltage, and frequency services to the grid in place of power transformer
  - Reduce cost by substituting aqueous chemistry-based flow batteries for traditional copper-centric transformers
  - Gaining the benefits of energy storage without having to pay for both transformers and energy storage

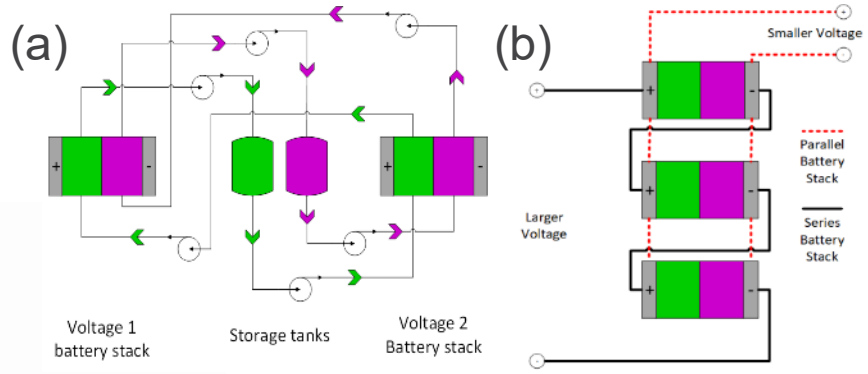


Figure 1 *(a) Voltage transforming battery schematic using flow batteries and (b) different cell stack arrangements for achieving different voltages.*

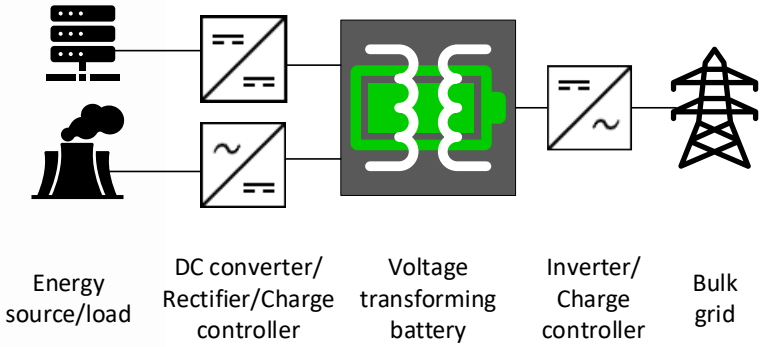
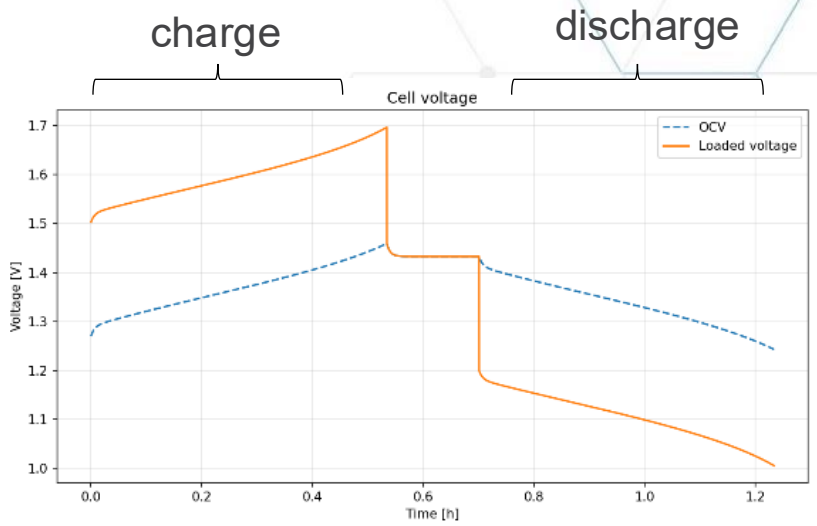
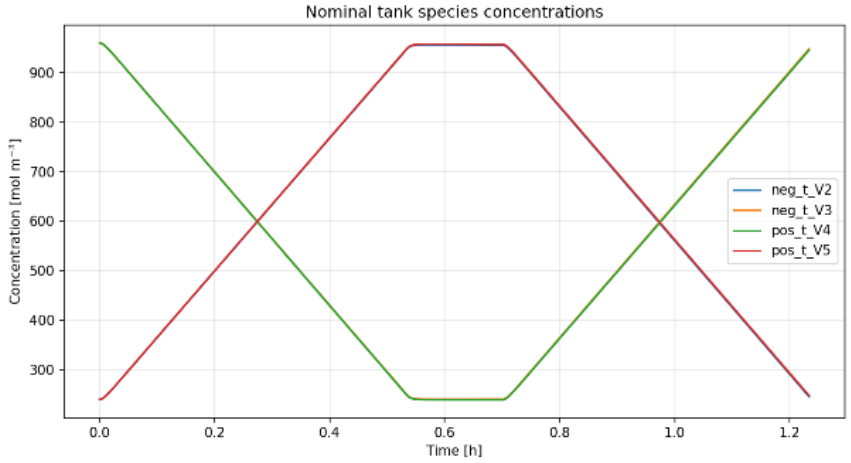


Figure 2 *Schematic of how voltage transforming batteries replace transformers.*

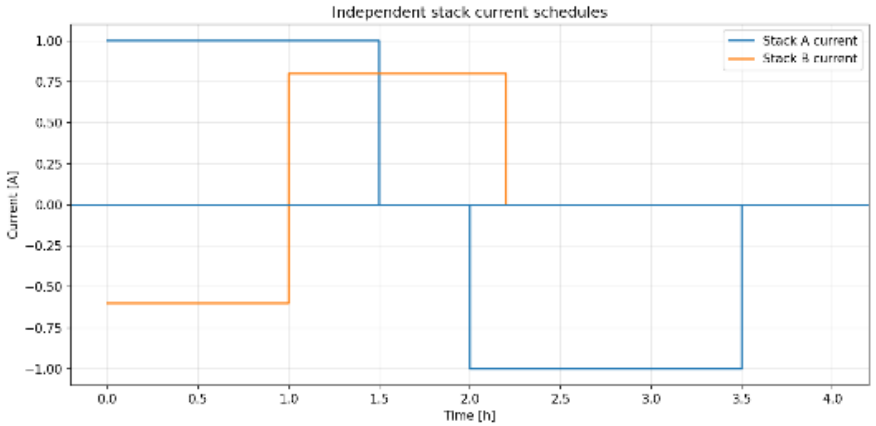
VTB success stories: *modeling*

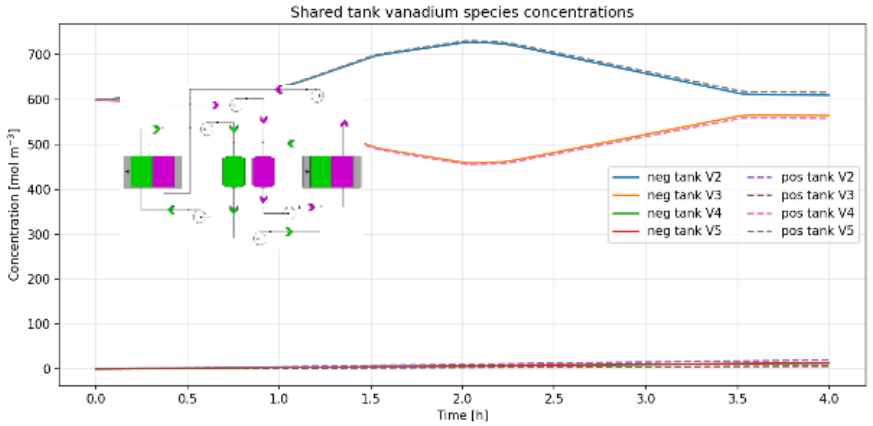
- Modeled vanadium flow battery single cell
  - Includes mass balance equations
    - Shah's transport-and-kinetics
    - Tank-cell ordinary difference equations
- Voltage is higher during charging and lower during discharging
- Coulombic Efficiency: 99.7%
  - Measures the amount of charge that can be recovered during discharge
- Voltage efficiency: 69.0%
  - Measures how close discharge voltage is to the charge voltage
- Energy Efficiency: 68.8%
- State of charge range from 20%-80%
- Competing against highly efficient transformers, but acceptable efficiency can be gauged case by case

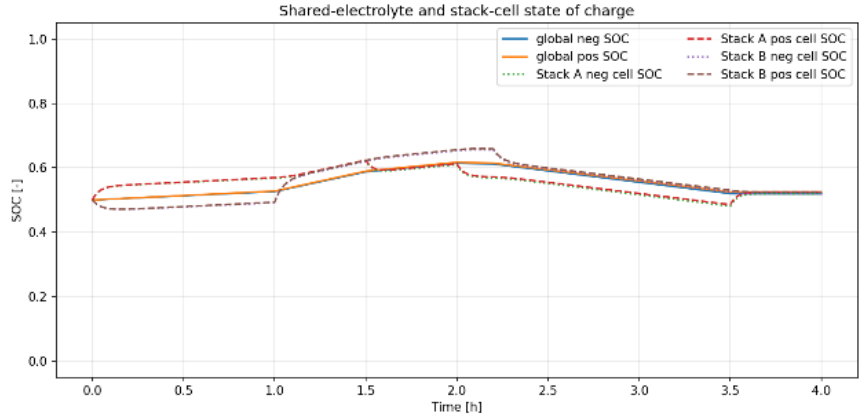


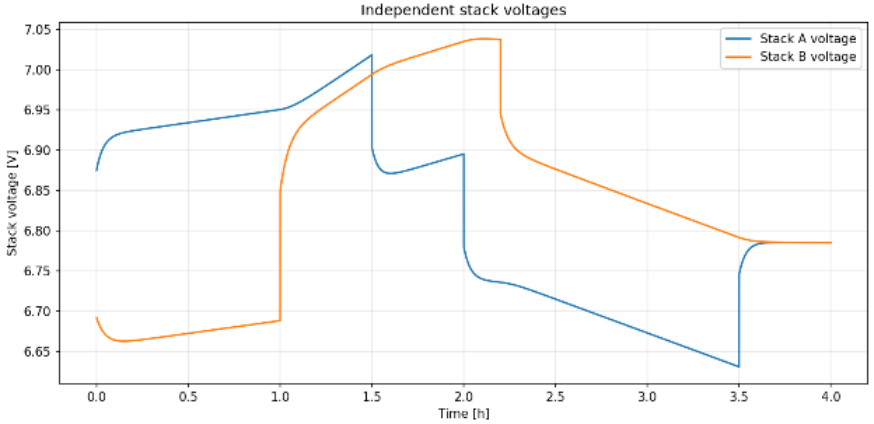


VTB: *initial VTB simulation results*



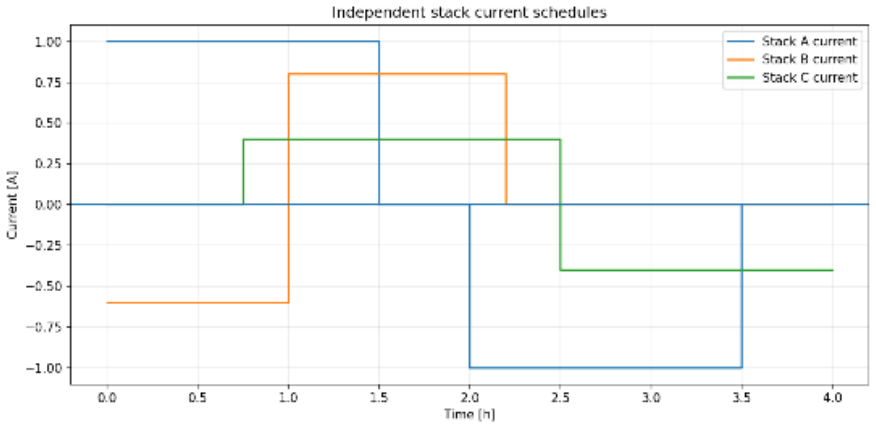


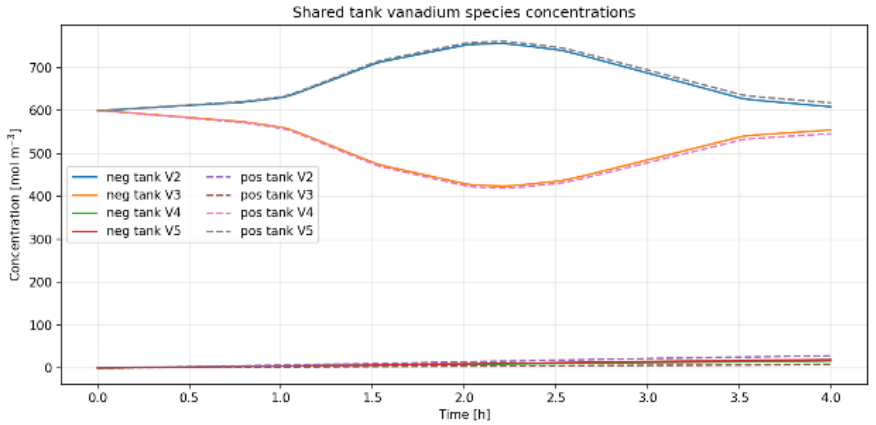


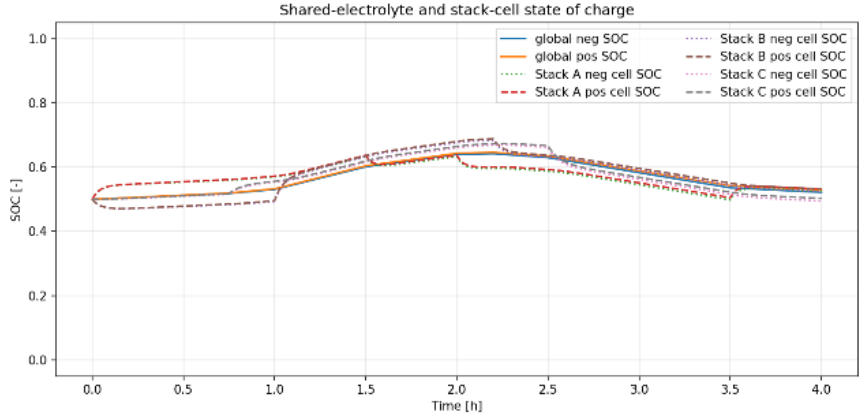


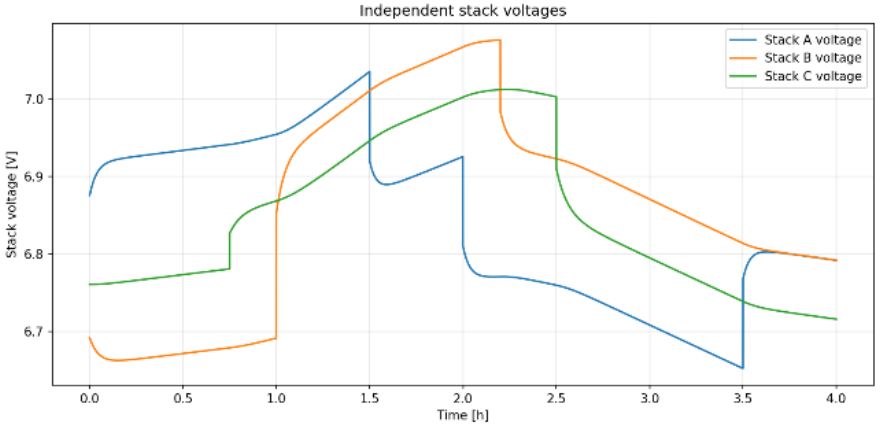
Global Energy Efficiency: 82.0%

VTB: *initial VTB simulation results*



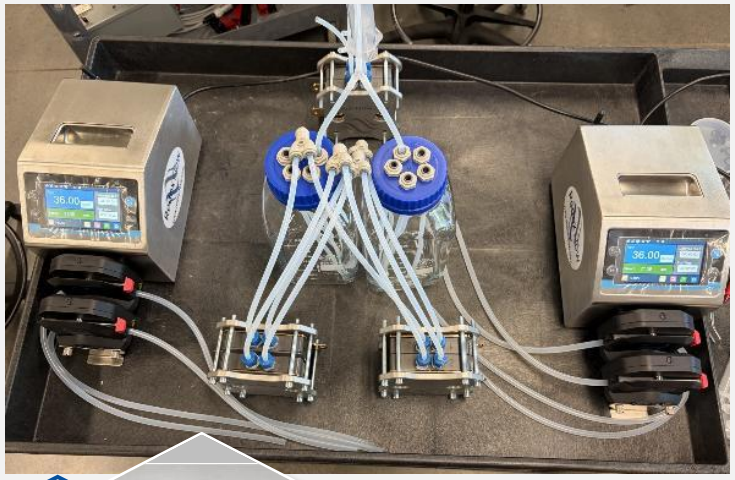






Global Energy Efficiency: 82.5%

VTB success stories: *testing*



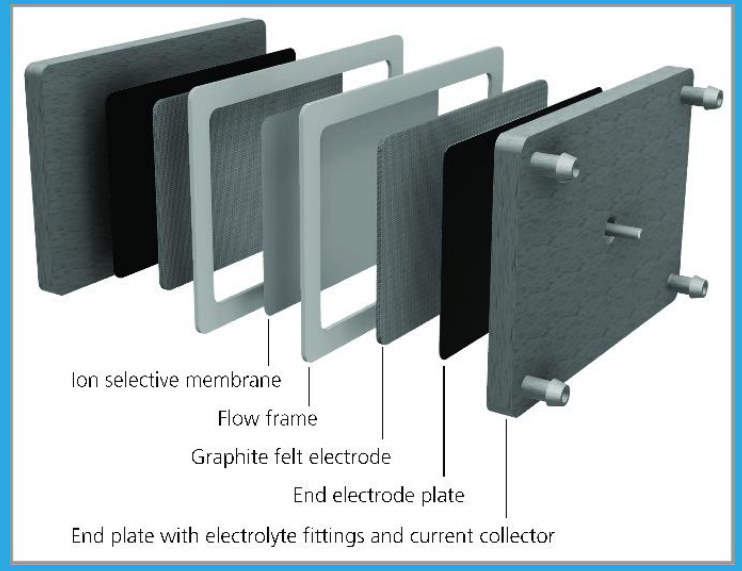


- Bench scale assembly in testing
- Electrolyte provided as in-kind contribution from Storion Energy
- Leak test using water flow complete
  - Tests with electrolyte have resulted in leaks which require further troubleshooting
  - Benchmarking and VTB stack testing set to be complete by 9/30
- Battery cycling with a visible color change

- Flow rate balancing
  - Initially 60mL/min with clear changes based on flow rate and voltage limit set
  - Battery cycling with a visible color change
  - No transformer or electrochemical characterization completed as of July

Potential follow-on research project: *VTB scalability*

- Invinity Energy Systems can provide a unit and grid interfacing components for small-scale microgrid integration
- Potential future testing and demonstration at INL's Energy Technology Proving Ground





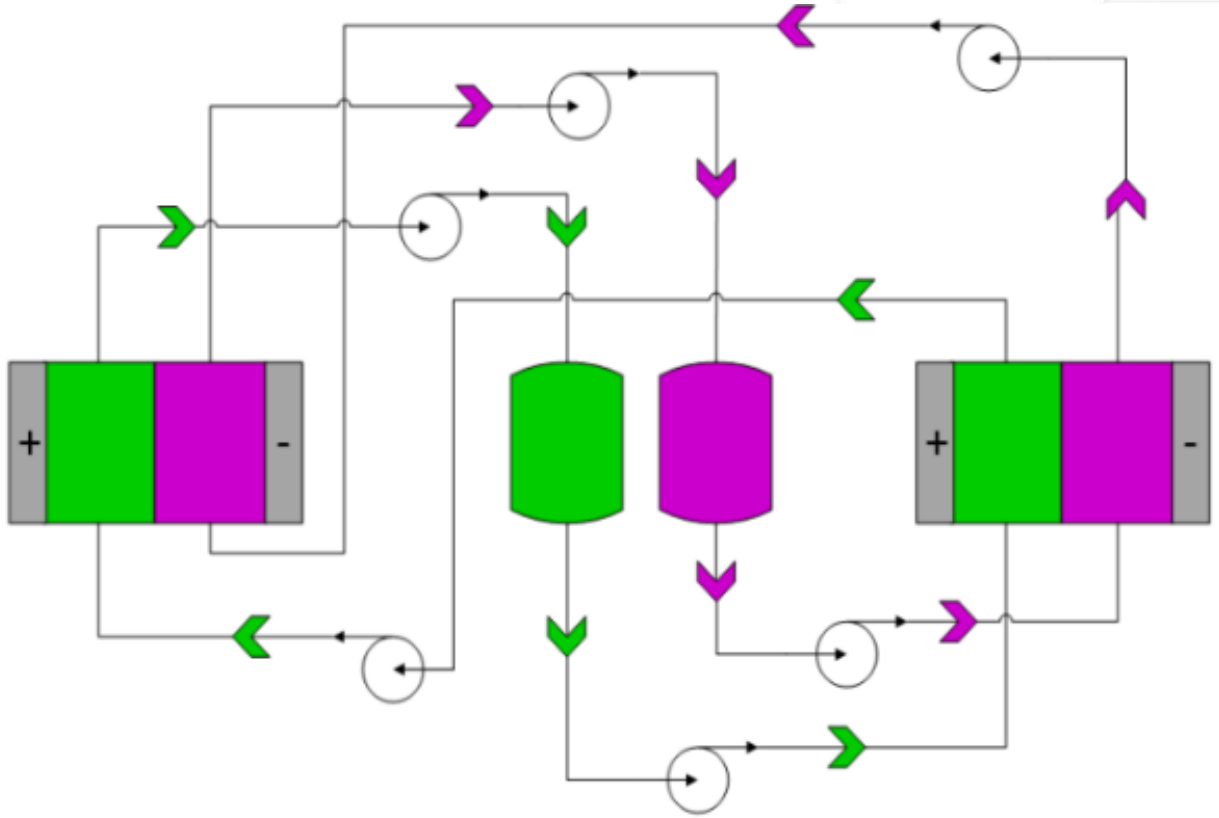
VTB: *publications and technology transfer*

BA-16634 Voltage transforming batteries

- INL office submitting provisional patent

Journal paper submission planned

- Targeting “Applied Energy” and “Journal of Energy Storage”
- Submission end of September



Acknowledgements

- This material is based upon work supported by the U.S. Department of Energy, Office of Electricity (OE).
- Storion Energy provided the electrolyte for the VTB lab setup
- Invinity Energy advised on the VTB design



Idaho National Laboratory

Battelle Energy Alliance manages INL for the U.S. Department of Energy's Office of Nuclear Energy. INL is the nation's center for nuclear energy research and development, and also performs research in each of DOE's strategic goal areas: energy, national security, science and the environment.