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CEC- CRADA UPDATE ON LONG DURATION ENERGY STORAGE TECHNOLOGIES ANALYSIS

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PROJECT PROFILE
Topic: Demonstration projects Vertical: Grid Integration and Field Validation
Strategic Pathway: Optimize and Grow
Project start and finish: FY24-FY27

PROBLEM

- Several different types long duration energy storage (LDES) technologies are proposed for grid application. Critical evaluation of these technologies such as technology maturity, safety, ability to meet grid applications is needed to select projects for demonstration and field validation.
- Objective is to provide objective, unbiased technical analysis based on detailed literature analysis, SNL experience and expertise in the subject area.

Few Technology Options for LDES

- **Electrochemical Storage** (Batteries - short, medium, long duration storage)
  - **Lithium-Ion Batteries,**
  - Sodium-Ion Batteries, Molten Sodium Batteries
  - Zn-Based Batteries, Ni-H_2 batteries
  - Metal-Air Batteries
  - Flow Batteries
- **Mechanical Storage** (short, medium, long duration storage)
  - **PHS (Pumped Hydro Storage)**
  - Variations of PHS (Quidnet Energy, RCAM)
  - Gravity (ARES, Energy Vault)
  - Compressed air (CAES)
  - Flywheels (short duration storage)
- **Thermal Storage** (medium, long duration storage)
  - Molten salt thermal storage, ceramic particle storage media, Fixed bed thermal storage
  - Heated brick (Antora, Rondo)
  - Molten metal, liquid metal battery
  - Liquid air energy storage
- **Chemical and Hydrogen Storage** (long duration and seasonal storage)
  - H_2 generation (Electrolysis, SMR), H_2 storage, Electric Power generation (H_2 combustion, Fuel cells)
  - Hydrocarbon or ammonia conversion

Desired ES Characteristics:
- Ability to respond quickly for load demand
- High round trip efficiency
- Low self discharge
- High energy density
- Cost competitive
- Environment friendly
- Availability with good supply chain
- Safe

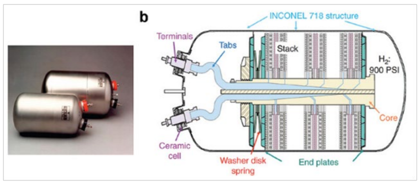
Fig. 1. An example of different energy storage technologies and desired characteristics

APPROACH

- California Energy Commission (CEC) funded a CRADA (collaborative research and development activity) at SNL to support the LDES efforts in CA.
- DOE-OE has similar goals to advance grid scale LDES technologies nationwide through field demonstrations and validation.
- Since the end product of this work is a technical analysis review report, a detailed literature review was performed. This includes supplier literature, published literature in the scientific journals on the subject matter, old SAND reports, talking to experts in this area, field visits when possible and utilizing the knowledge and experience of the author.
- Company literature often doesn't provide all the critical information. An unbiased independent detailed technical analysis would help make informed decisions.
- Sandia National Labs and the staff have several decades of experience in the development and evaluation of energy storage technologies, and we are uniquely positioned to provide detailed technical analysis.
- Briefly reviewed CEC data base consisting of more than 100 technologies and companies and provided a broad overview of different types of technologies, pros and cons. Detailed analysis was performed on four technologies (Ni-H_2 battery, A-CAES, Na-ion battery and supercapacitors as requested.

RESULTS

Ni-H_2 Battery (EnerVenue)



SAFT, Ni-H_2 battery

Ni-H_2 battery: combines the Ni electrodes from Ni-Cd batteries and H_2 electrode from fuel cells. Electrolyte is KOH, not flooded but contained within the separator.
Pros:
Proven space technology.
Good cycle life and calendar life (30 yrs, 30,000 cycles).
Wide operating temperature range: -10C to 45C.
A/C or liquid cooling is not needed, forced air cooling sufficient.
Operates over broad C-rates from C/2 to C/12.
Proven safe in battery abuse tests.
Cons:
Expensive Pt catalyst and zirconia cloth separator were used in space applications.
EnerVenue developed a low cost Ni-Mo-Co catalyst, and a low cost polymer separator. Service life performance is not known.
Battery Module Cylinders contains pressurized H_2 leading to safety concerns.
Rate of self discharge is not known.
Low energy density.

Fig. 2. Ni-H_2 battery proposed by EnerVenue and old SAFT battery example

A-CAES System (Hydrostor)

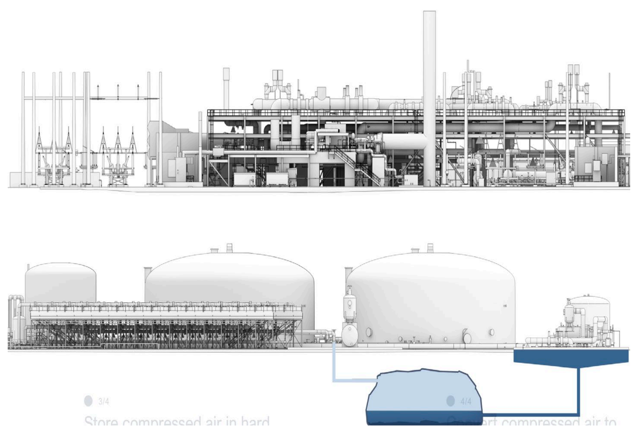


Fig. 3. A-CAES proposed by Hydrostor

Adiabatic – Compressed Air Anergy Storage (A-CAES- Hydrostor):
For 500MW approximately 100 acres area. 50 yr life time. Projected RTE: 60-70%.
Smaller prototype demo done in Canada. Several projects are in the pipeline, but larger systems are not built yet.
Charge/discharge Steps: Compress ambient air, store compressed air in custom built underground caverns. Capture the heat of compression through a heat exchanger and store the heat (storage media- oil?) in surface tanks. Caverns are initially filled with water. During charge, compressed air pushes the water into surface water tank. During discharge, this water head is used to supply constant air pressure for the generator turbine. Heat stored during compression is used to heat the air for power generation. Fossil fuels are not used to heat the air as is done in the diabatic compressed air energy storage systems like the one in McIntosh, AL.
Issues:
Larger system with high capital cost. Need large area, low energy density. Increased system complexity for efficiency gain. Full scale systems are not built yet to assess the performance.

CONCLUSIONS & IMPACT

- There are several promising LDES technologies that are suitable for grid scale energy storage. Many of these are still in the early stages of commercialization, looking for capital, state or federal support and opportunities for field demonstrations.
- Examples shown above are two case studies with pros and cons, SNL is not endorsing any of these technologies or companies.
- Continuing cost reductions and safety improvements of Li-ion batteries, especially LFP batteries is putting lot of pressure on the <8 hr energy storage market. In light of this most flow battery companies are changing their strategy from 4-6 hr duration target market to 10-36 hr duration to be competitive.
- Market is not well developed for 100+ hr storage for resiliency applications.

FUTURE DIRECTIONS

- Continue to monitor the current state of various technologies and companies, and perform analysis as requested.
- Compile the summary info into a SAND report.

References

Few examples of Old SAND reports on Ni-H_2 battery: SAND 84-7155, 87-706, 88-0435, 90-0390. NASA Tech Memorandum 83647, 82844. EnerVenue patents: US11855294 B2, WO2019/032704A1, US2022/10416252, US2023/0282890, US2024/0097241.
Wei Chen, Yang Jin, Jie Zhao, Nian Liu and Yi Cui, Nickel-Hydrogen batteries for large scale energy storage, LNAS, Nov 13, 2018, Vol. 115, mo. 46.

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