Alternative Storage Solutions for Stationary and Standby Applications

Safety and Reliability of Non-Lithium Storage

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The Goal

Why are we here?

The goal of the ESS Safety and Reliability Forum is to provide a platform for discussing the current state of ESS safety and strategies for improving cell-to-system level safety and reliability.

Specific topics and areas to be discussed in this forum include (but are not limited to): 1) designing safer energy storage systems, 2) early detection for intervention, 3) safety and reliability of non-lithium-ion technologies, 4) energy storage safety codes and standards, 5) ensuring safety during operation, 6) responding to a safety event, and 7) lessons learned from a safety incident.

I would like to focus on the non-lithium technologies, their safety, reliability, and the ESS Codes and Standards that apply to them.

Designing Safer ESS

What do we mean by ”safer”?

Safer than what?

Changing landscape!

Lead-Acid set the standard for over 100 years. In the last several decades, other technologies have emerged - presenting new issues and challenges.

- Nickel-Cadmium exhibited memory issues.
- VRLA presented both reliability and life-cycle challenges.
- Nickel Metal-Hydride presented charging challenges.
- Lithium now presents challenges in volatility and toxic gas production.

Ripple Effects

Codes and Standards Reaction.

- New technologies raised concerns. The risks to safety and reliability were unknown.
- Due to some of these issues, Codes and Standards had to change dramatically!
- Model Codes had to be altered drastically.
- Standards from many organizations had to be rewritten and new Standards created to meet the changing landscape.
- Code and Standard revisions, additions, and internal modifications have accelerated at an increasing rate in the last several years.

Safety and Reliability

What options do we have?

A Real Path to Safety

Remove the hazard, remove the risk.

- Most of the aqueous technologies have already been subjected to the UL 9540A Test Method and don’t exhibit thermal runaway.
- Most of these technologies don’t require individual cell management, but monitoring is always a good idea.
- When properly applied, the reliability of these technologies is extremely good.
- Some are old technologies that have been updated. Others have existed as primary cells and new developments have allowed use as secondary cells.

Currently Available Technologies

Something for each application.

Aqueous Alkaline	Flow Batteries	Sodium Ion
Nickel-Iron	Polysulfide-Bromide	Sodium-Metal Chloride
Nickel Metal-Hydride	Vanadium Redox	Sodium-Nickel Chloride
Nickel-Zinc	Zinc-Air	Sodium-Metal Halide
Silver-Zinc	Zinc-Bromine	Sodium Sulfur
Zinc-Air	Zinc-Chlorine	
Zinc Manganese Dioxide		

A Variety of Solutions

Energy storage for many uses.

- **For short duration** (up to 15 minutes), high power applications, Nickel-Zinc and Nickel Metal-Hydride are available. Sodium Batteries (High Temperature) can fill some applications.
- **For medium duration** (1/4 hr. to 8 hr.) energy applications, Zinc Manganese Dioxide and some Nickel Metal-Hydride options are available. Some flow batteries become efficient in these medium durations.
- **For long duration** (1 hr. to 48 hr.) energy applications, several flow batteries are available, as is Zinc Manganese Dioxide.

ESS Codes and Standards

What changes have been made?

The Landscape

What Codes and Standards matter for ESS?

- In North America, we deal with two Model Codes relating to ESS.
- There are several Standards published by **NFPA**, **ICC**, **UL**, and others.
- There are **IEEE Recommended Practices and Guide Documents** that should be considered.

Let's look at these in more detail:

Model Codes

The "Fire Codes"

National Fire Protection Assoc.

National Fire Code NFPA-1

- The 2018 revision already contained some restrictions for lithium and “other” technologies.
- Sodium and flow batteries have already been recognized and limited, as have capacitors.
- All other technologies were lumped under “other” technologies.
- There have been several (sometimes conflicting) standards regarding battery safety.
- One-hour rated separation was generally considered adequate.

International Code Council

International Fire Code - IFC

- 2018 revision was worded very similarly to NFPA-1.
- IFC-2018 did have minimum threshold capacities for lead-acid and NiCad, which NFPA-1 did not have.
- IFC-2018 was more stringent in the requirements for installation of non-listed battery types.
- Both NFPA-1 and IFC 2018 required a Hazard Mitigation Analysis for non-listed batteries.

Big Changes!

Both model codes significantly revised.

In response to the rapidly changing landscape of battery technology, and because of lessons learned with early lithium installations, both NFPA-1 2021 and IFC 2021 were substantially rewritten.

- NFPA-1 was revised to point all ESS related safety requirements to NFPA 855 2020 (published in November of 2019).
- IFC 2021 was revised to include much of the language contained in NFPA 855 2020.
- Some of the listed electrochemical systems in NFPA 855 were not included in the IFC 2021.

Standards

The real safety testing arena.

How Standards affect Codes

Where the rubber meets the road.

- When cited in the Model Codes, Standards become part of the Code.
  - NFPA 1 2021 has 454 reference documents cited.
  - IFC 2021 has more than 290 referenced documents cited.
  - Both Codes cross-reference the other organization's Standards. In addition, they also cross-reference Standards in UL, CSA, IEC, ASTM, as well as other organizations.
  - As such, the Standards are, for the largest part, common between the two Codes.

The Major Influencers

Standards that really affect the Code base.

- NFPA 855 – Major influence for NFPA 1 and IFC
    - 2020 revision significantly increased safety requirements for ESS installations.
    - 2023 revision continues to advance the safety requirements, while clarifying many aspects of the earlier revision.
- UL 1973 – Recent updates to this Standard increase its importance
- UL 9540 – Applies primarily to ESS in grid-tied applications
- UL 9540A –Required for all non-listed electrochemistries
    - A recent CRD requires Lead-Acid and Ni-Cad to be tested to UL 9540A or using UL 1973 Annex H overcharge method.

IEEE Documents

Recommended Practices and Guides

The IEEE 1679 Document Family

IEEE ESSB document development.

The IEEE PES Energy Storage and Stationary Battery Committee (ESSB) has been working to develop documents covering these alternative chemistries.

- IEEE 1670 2020 is a recommended practice establishing guidelines for characterizing and evaluating these alternative chemistries.
- Four "child" documents cover the various classes of products.
    - Two (IEEE 1679.1 – Lithium, and IEEE 1679.2 – Sodium) are published guide documents following the 1679 2010 format.
    - Two (IEEE P1679.3 – Flow, and IEEE P1679.4 – Aqueous Alkaline) are still in development as guides for those chemistry classes.

The IEEE 1679 Document Family (2)

IEEE needs participants.

- IEEE 1679.1 2017 is now in revision as P1679.1 Guide to the Characterization and Evaluation of Lithium-Based Technologies.
- IEEE P1679.3 Draft Guide for the Characterization and Evaluation of Flow Batteries is currently in development.
  - Expected publish date: 2024
- IEEE P1679.4 Draft Guide for the Characterization and Evaluation of Aqueous Alkaline Batteries is currently in development.
  - Expected publish date: 2025

Questions?

Thank You!

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