Alternate Battery Technologies for UPS Applications*

Presented by

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We Will Discuss:

• What Is A Battery?
• Why Do We Use Batteries?
• Alternatives to Batteries
• New Battery Technology Case Study
• Lithium Battery Primer and Risk Mitigation
• Panel Questions and Answers
What is a Battery?

- A container consisting of one or more cells, in which **chemical energy** is converted into electricity and used as a source of power.
- Batteries developed from Capacitors using a chemical process to provide significantly larger stored energy sources.
Concise History of Batteries

1745
First Capacitor
Invented by
Peter Van Musschenbroek

1749
Term “Battery”
used by
Benjamin Franklin

1801
First Battery
Invented “Leiden Jar” by
Alessandro Volta

1859
First Rechargeable
Battery Lead Acid
by Gaston Plante

1899
Invention of the
Nickel Cadmium
Battery

1970s
Development of
Sealed Lead Acid
Battery (VRLA)

1990
Commercial Distribution of
Nickel Metal Halide Battery

1992
Commercial Distribution of
Lithium Batteries

1999
Commercial Distribution of
Lithium-Ion Battery
Why Do We Use Batteries?

- Local source of stored energy
- Instant current available
- Stored energy source must be reliable
- Batteries provide the balance between stored energy and the ability to deliver that power quickly
- Batteries, using a chemical reaction, are consistent and predictable?
Common Issues With Lead Acid Batteries

- Drying Out
- Thermal Runaway
- Open Cell or Defective Internal Connections
- Deterioration Over Time; Rapid at End of Life
- Over Charging; Under Charging
- Extensive Maintenance and Monitoring
Alternatives to Batteries

- **Flywheel**
  - Stored energy is mechanical
  - Small footprint
  - Fast recharge
  - Long service life
  - Low runtime
  - High upfront cost
Alternatives to Batteries

• **Fuel Cells**
  - Stored Energy is Chemical
  - Must store hydrogen (flammable)
  - Natural Gas source requires heat source
  - Clean emissions
  - High runtimes (based on fuel storage)
  - Low instant current potential
Alternatives to Batteries

• Supercapacitor
  – Stored energy is Electrical
  – Low runtime
  – Low quantity of energy
  – Wide temperature range
  – Low/No maintenance
New Battery Storage Technologies
BB&T Case Study, 2012

• Baseline for Comparison
  – Wet Cell and VRLA (Lead Acid, PbSO4)

• Alternative Battery Technologies
  – Molten Salt Battery, Sodium Nickel Chloride (NaNiCl)
  – Lithium Iron Phosphate (LiFePO4)
  – Lithium-ion Nickel/Cobalt/Aluminum (Li-ion NCA)
Sodium Nickel Chloride Battery

Benefits
• Minimal footprint, low weight
• Reliable – a cell failure does not fail the battery system
• Works in any temperature range
• Extremely safe (no gassing or potential for explosion; non-toxic)
• No “whiplash” (Coup de Fouet) at initial discharge
• Zero degradation, practically infinite shelf life
• No self discharge

Drawbacks
• Cost (however, TCO is predicted to be superior)
• Manufacturing and maintenance are limited
• Requires significant energy to keep heated
• Higher float voltage (may not be compatible with legacy UPS)
Li-ion NCA Battery

Benefits
- Easily adaptable to any UPS architecture
- Minimal footprint, much lighter than lead acid
- High reliability
- Less toxic, lower environmental risk
- Faster recharge

Drawbacks
- Shorter runtime for similar cost of Lead Acid
- Battery capacity diminishes over time
- May suffer thermal runaway or rupture if overheated or overcharged
- Manufacturing is limited at this time
- Maintenance and support may be limited
LiFePO4 Battery

Benefits
• Minimal footprint, much lighter than lead acid
• Minimal maintenance
• Integrated safety systems to protect against short circuit, overvoltage and over discharge
• Minimal gassing
• Excellent predicted TCO
• Low toxicity, easily recycled

Drawbacks
• Not well tested in mission critical applications
• Shorter runtime for similar cost of Lead Acid
• Manufacturing is limited at this time
• Maintenance and support may be limited
• Higher float voltage (may not be compatible with legacy UPS)
## Safety

<table>
<thead>
<tr>
<th>Battery</th>
<th>Transport</th>
<th>Gassing</th>
<th>Chemistry</th>
<th>BMS</th>
<th>Toxicity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lead Acid</td>
<td>Ground/Air</td>
<td>High (H₂)</td>
<td>Acid</td>
<td>Not required</td>
<td>High</td>
</tr>
<tr>
<td>NaNiCL</td>
<td>Ground/Air</td>
<td>None</td>
<td>Salt</td>
<td>Required</td>
<td>Low</td>
</tr>
<tr>
<td>LiFePO4</td>
<td>Ground</td>
<td>Minimum risk</td>
<td>Non-metallic</td>
<td>Required</td>
<td>Low</td>
</tr>
<tr>
<td>LiNiO</td>
<td>Ground</td>
<td>Minimum risk</td>
<td>Non-metallic</td>
<td>Required</td>
<td>Low</td>
</tr>
</tbody>
</table>
## Alternative Battery Technology

### Proof of Concept

<table>
<thead>
<tr>
<th>Vendor</th>
<th>Tech.</th>
<th>Delivery</th>
<th>Initial Cost</th>
<th>Yearly Electric Cost</th>
<th>Yearly Maint. Cost</th>
<th>Life</th>
<th>Cost per year</th>
<th>10 year life compare</th>
<th>Cost per year</th>
</tr>
</thead>
<tbody>
<tr>
<td>GE</td>
<td>NaNiCL</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Vendor withdrew from the bidding, not pursuing the UPS battery market at this time.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A123</td>
<td>LiFePO$_4$</td>
<td>90 days</td>
<td>2.6X</td>
<td>$0</td>
<td>$0</td>
<td>20</td>
<td>0.5X</td>
<td>10</td>
<td>1.0X</td>
</tr>
<tr>
<td>Saft</td>
<td>LiNiO</td>
<td>112 days</td>
<td>5.1X</td>
<td>$0</td>
<td>$0</td>
<td>20</td>
<td>1.0X</td>
<td>10</td>
<td>1.9X</td>
</tr>
<tr>
<td>Various</td>
<td>VRLA</td>
<td>In Stock</td>
<td>Base Line = X</td>
<td>$63</td>
<td>$580</td>
<td>4.5</td>
<td>Base Line = X</td>
<td>4.5</td>
<td>Base Line = X</td>
</tr>
</tbody>
</table>
Case Study Findings

• Reduced risk with Lithium Batteries:
  – Established technology; more predictable.
  – Eliminates lead usage, acid spills, hydrogen discharges, and thermal runaway risk.
  – Less battery replacements over life reduces maintenance risk.

• Reduced cost:
  – Increased life of 20 years compared to 4.5 years.
  – No regular maintenance or trickle charging needed for Lithium.
  – Comparable TCO @ 10 year; Cost savings $0.5X per year @ 20 year.
  – Reduces footprint and weight by ~50% for Lithium batteries.
Primer on Lithium Batteries and Risk Mitigation
Lithium-ion technology

- The most commercialized advanced battery technology
- Family of electrochemical systems
  - Different voltage characteristics
- Positive electrode
  - Metal oxides (e.g. NMC, NCA)
  - Phosphates (e.g. LFP)
- Negative electrode
  - Graphite & other carbons
  - Lithium titanate
Lithium-ion architecture

- Configurable for power or energy applications
- Highly modular construction
- Built-in monitoring & management electronics will take individual strings offline if problems exist
- Parallel Architecture (N + 1 redundancy or better)
Why Lithium Batteries?

- Superior Power Density
- High Discharge Rates
- Faster Charging
- Excellent cycling capability
- ~95% round trip efficiency
- Long Float Operational life (20 years)
- Maintenance-free and self-diagnosing
- Lower environmental footprint
Lithium-ion holistic safety approach

- No battery chemistry is intrinsically safe!
- Four pillars concept for Li-ion
  - Each pillar equally important
- Multiple redundant layers
  - Cell level – safe venting
  - Module level – no propagation!
  - String level – protective devices & algorithms
  - System level – active comms for safe operation & alarm management
- Auxiliary systems – fire detection & suppression
Panel Questions and Answers

Steve Babechenko, First Citizens
Scott Ryberg, Syska Hennessy Group
Joe Colucci, Whiting-Turner
Jim McDowall, Saft America Inc.
Panel Questions & Answers

• Fire and fire suppression is a big concern of end users for Lithium; what is the industry doing in this regard?

• What alternate energy storage (Flywheels, Supercaps, Lithium) do you see being used at critical facilities?

• Are UPS manufacturers adopting Lithium and other battery technologies?