WHITE PAPER

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Born to Innovate

The Rising Trend Toward Li-Ion Batteries in UPS Solutions

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Introduction

Lithium-Ion (Li-Ion) batteries are not something new. Li-Ion batteries have been in use commercially for well over 20 years, having first appeared in commercial applications in the 1990s. Lithium-Ion cells first came into prominence as non-rechargeable batteries for use in small consumer products such as cameras and remote control toys. Today most people associate rechargeable Li-Ion batteries with personal/portable devices as they have become the rechargeable battery cell of choice in cellular phones, tablets, and small personal wearable appliances. However, the breadth of Li-Ion batteries includes both non-rechargeable and rechargeable cells using many different chemistries for use in many different applications.

More recently, Li-Ion battery cells have become a more common solution in Electric Vehicles, E-bikes, UPS' and Energy Storage devices, which look to take advantage of their higher energy density, longer life, improved discharge cycles, better energy efficiency, and lesser environmental impact versus the Valve-Regulated Lead-Acid (VRLA) batteries that have previously dominated these applications.

Many Types of Li-Ion Cells

The term Lithium-Ion battery may be a bit confusing or misleading since there are many different chemistries that are used in Li-Ion batteries. Examples of the different cell chemistries are:

- Lithium Cobalt Oxide (LCO)
- Lithium Nickel Manganese Cobalt (NMC)
- Lithium Manganese Oxide (LMO)
- Lithium Nickel Cobalt Aluminum (NCA)
- Lithium Iron Phosphate (LFP)
- Lithium Titanate (LTO)

Each Li-Ion chemistry has its advantages and disadvantages from size/weight, energy density, cycle life, nominal voltage, stability, and a host of other items.

THREE (3) OF THE MOST COMMON CHEMISTRIES ARE:

LCO (Lithium Cobalt Oxide)

This is one of the smallest and lightest of Li-Ion battery cells and is used in cell phones and small personal devices, etc. It has a high nominal voltage and very high energy density but has a relatively low cycle life and thermal runaway temperature, making LCO one of the more volatile of Li-Ion battery chemistries.

LFP (Lithium Iron Phosphate)

This is one of the largest/heaviest of Li-Ion battery chemistries and is used by Telcos in large energy storage applications and commercial vehicles like golf carts and forklifts. It has a lower nominal voltage, long cycle life, but a relatively low energy density with a high thermal runaway temperature, making it one of the most (thermally) stable Li-Ion chemistries.

NMC (Lithium Nickel Manganese Cobalt)

This battery chemistry is light, has high nominal voltage and energy density, long cycle life, and falls in the middle between LCO and LFP chemistries. NMC is a common chemistry in the extremely popular 18650 battery cells, which get their name from their size (18mm by 65mmm).

COMPARING THESE THREE COMMON LI-ION BATTERY TYPES:

Battery Type	LCO	LFP	NMC
Nominal Voltage	3.6V	3.2V	3.7V
Energy Density	160-200Wh/kg (up to 240Wh/kg)	85-120Wh/kg	150-220Wh/kg
Typical Cycle Life*	1000	2000+	1500-2000
Thermal Runaway	150°C	270°C	210°C
Applications	Cell phones, cameras, tablets, laptops	Energy storage, high load current, and endurance applications	Electric vehicles, E-bikes, industrial, medical

*Cycle Life - dependent on depth of discharge, temperature, and load - LCO
- dependent on depth of discharge and temperature - LFP and NMC

Li-Ion Batteries as an Alternative to VRLA Batteries

Looking into the differences between battery cell types, Lithium-ion batteries use a different chemical process than VRLA or “flooded” lead-acid batteries. In a Li-Ion battery cell, the charged lithium-ion moves back and forth between the positive and negative plates through an electrolyte of lithium salt in an organic solution. Different combinations of chemicals, as described in the previous section, can be used for the cathode and anode, with the most common types being Lithium Cobalt (LCO), lithium iron phosphate (LFP) or nickel, cobalt, and manganese (NCM).

In a lead-acid battery, the negative electrode is made of porous lead to facilitate the formation and dissolution of lead, while the positive electrode consists of lead oxide. The electrodes are immersed in a solution of sulfuric acid and water, hence the name Lead-Acid. The two electrodes are separated by a chemically permeable membrane, which helps prevent electrical shorting through the electrolyte.

Differences in cell construction

between Li-Ion and Valve-Regulated Lead-Acid (VRLA) or flooded lead-acid batteries

Li-Ion batteries have become an attractive alternative to Valve-Regulated Lead-Acid (VRLA) batteries in many design applications. While Li-Ion batteries are still more costly than VRLA batteries, the cost delta has been coming down. As improvements are made to existing technologies, consumption increases (driven primarily by the demand for smartphones, smartwatches, activity trackers, and tablets, particularly from developing countries), and new Li-Ion chemistries are introduced, the price of Li-Ion batteries should continue to decrease and the cost delta between Li-Ion and VRLA should shrink even further.

As such, designers are starting to take advantage of the higher energy densities, smaller physical size, lighter weight, low maintenance, recyclability, and longer life characteristics of Li-Ion batteries and using them in more and more design applications.

Key reasons why Li-Ion batteries make sense in UPS designs

SIZE AND WEIGHT MATTER

Compared to VRLA batteries, Li-Ion batteries are much smaller and lighter. Li-ion batteries, on average, weigh 60-75% less and take up only 40-50% of the size (footprint) of equivalent VRLA batteries. Another way to look at this is for the same amount of battery capacity (Wh), Li-Ion batteries take up roughly half the space of their VRLA equivalent.

Taking ventilation requirements and/or the need for VRLA batteries to be located in a separate room into account, the footprint required for Li-Ion batteries and the cost associated with that space, reduce even further.

Less size and weight can also contribute to savings in shipping, handling, and deployment costs. When a Li-Ion UPS is used in an In-Rack or In-Cabinet power architecture, it may consume 2U to 3U of rack space, while a VRLA UPS of the same capacity would consume 5U to 8U of rack space. Using the Li-ion UPS would allow the user to "reclaim" 3U to 5U of space, which can be dedicated to revenue-producing IT equipment.

LONGER LIFE AND LOWER TCO

Li-Ion batteries have a longer life than VRLA batteries. On average, the lifespan for VRLA batteries is three to five (3 to 5) years, while Li-Ion batteries have an average lifespan of seven to ten (7 to 10) years. This equates to, on average, two (2) service maintenance schedules to replace VRLA batteries over a UPS product's lifespan. Using Li-Ion batteries in that same UPS application virtually eliminates the need for battery replacements.

The initial capital outlay for a Li-Ion UPS solution is roughly 1.75-2x the cost of the same capacity VRLA solution. However, once you factor in the costs of replacing lead-acid batteries every 3-5 years (and include the labor, shipping, travel costs associated with battery replacements), the Total Cost of Ownership (TCO) starts to favor the Li-Ion UPS over the life of the UPS deployment. This can be particularly relevant when the UPS is located in remote locations or remote data centers.

HIGHER AMBIENT TEMPERATURE TOLERANCE

There are a number of environmental conditions that can further reduce the life of VRLA batteries but operating in higher ambient temperatures is a major contributor. VRLA batteries work best at room temp 25°C (77°F), and for every 8.3°C (15°F) increase in temperature above room temperature, the life of the battery can be reduced by as much as 50%. Li-Ion batteries can operate at ambient temperatures up to 40°C (104°F) with little to no impact on battery performance or life.

THE EFFECTS OF CHARGING AND DISCHARGING ON BATTERIES

Charging, discharging, and the effect it has can vary greatly when comparing Li-Ion batteries to VRLA batteries. VRLA batteries start losing capacity from the very first charge/recharge cycle and continue to lose capacity with every charge and discharge cycle thereafter. VRLA batteries reach their "end of useful life," which in a UPS is generally defined as when the batteries hit 80% of their rated capacity in ampere-hours, much more quickly than Li-Ion batteries. Li-Ion batteries have a higher cycle life for a given depth of discharge, and depending on the chemistry, they can withstand more than 2000 charge and discharge cycles with minimal impact on capacity.

BATTERY FLEXIBILITY

The superior cycle performance of Li-Ion batteries also makes them more versatile than VRLA batteries. Li-Ion UPS' can be designed to use the battery pack to supplement the AC grid, in addition to using them for the 'normal' back-up power source during power outages. Using the Li-Ion batteries to supply supplemental power is referred to as Peak Shaving (or Peak Boost). This allows the UPS to set a power threshold 'cap' that it draws from the AC grid, allowing the Li-Ion batteries to provide additional or supplemental power consumed by the IT load.

Please see the Enconnex Peak Shave Application Note and/or our blog "How Peak Shaving Technology Can Reduce Energy Costs in Your Data Center."

STORAGE AND LONGEVITY OF BATTERIES

Li-Ion batteries exhibit a low capacity to fade/self-discharge when stored properly. Proper storage would have the Li-Ion batteries in a semi-charged state, which is ideally 35-40% of the fully charged value. This semi-charged state prevents the batteries from potential negative impacts (safety, stresses on cell, low voltage state) of being stored at full capacity. When ready, the batteries can be charged to 100% and will be ready for use. If Li-Ion batteries are stored properly in a room temperature environment (0-25°C), they can be stored for many years with minimal loss of battery capacity.

When VRLA batteries are not in use, it is recommended that they should be charged every three to six months to prevent loss of capacity and/or damage to the cells. If not stored properly, they can suffer permanent loss of capacity after only 18 months (if not periodically charged during storage).

ENVIRONMENTAL IMPACT

The good news about lead-acid (VRLA) batteries is that they are over 99% recyclable. The bad news is lead, which is the main component of these batteries, is a heavy metal that can have adverse health impacts. While leaded gasoline and lead-based paints were eliminated from use nearly 50 years ago due to environmental and health-related concerns, over 80% of today's lead consumption is due to the lead content in lead-acid (VRLA) batteries. That still makes lead the biggest environmental concern when using the batteries, since exposure can possibly take place during mining, processing, and the recycling of the lead.

In less developed countries where mining and/recycling is more poorly regulated, the potential for human exposure and environmental contamination is still an unfortunate reality. Lead-acid batteries can find their way into landfills and recycling of lead in some of the less developed countries can be conducted without the necessary processes to control lead emissions and contamination.

The lithium in Li-Ion batteries is not a huge concern in terms of pollution. However, depending on the chemistry of the Li-Ion cell, they may contain manganese, cobalt, or nickel, which while not considered as toxic as lead, are still classified as toxic heavy metals, so Li-Ion batteries are not 100% without environmental concerns.

The good news is companies are working on the complete recycling of Li-Ion batteries. About 80% of the contents, by weight, of Li-Ion cells is steel and copper, which is nearly 100% recyclable, and technologies are being developed to recycle the rest. The goal is for Li-ion batteries to be recycled at rates as high as lead-acid batteries.

Conclusion

In terms of the next generation UPS designs, the goal at Enconnex is to get the lead out! Our AC6000 Li-Ion UPS is a single-phase UPS, providing up to 6kVA/6kW of uninterruptible power in a small 2U form factor. It combines an efficient Line-Interactive topology and industrial-grade Li-Ion battery pack, allowing for up to 12 minutes of runtime at 50% load (3kVA/3kW), up to 6 minutes of runtime at full load (6kVA/6kW), and a fast recharge time to 90 percent battery pack capacity in less than 1 hour. And be on the lookout for additional Li-Ion UPS products from Enconnex.