VERTIV WHITE PAPER

Safety Rules

An Update on Lithium-ion Battery Use in Critical Facilities

Introduction

Lithium-ion batteries (LIB) offer many benefits when used in conjunction with data center uninterruptible power supply (UPS) systems. Industry experts are predicting lithium-ion batteries have the potential to revolutionize data center facility design. Still, data center professionals have legitimate questions about the operational and safety aspects of this emerging technology and how it compares to traditional valve-regulated, lead-acid (VRLA) batteries.

Lithium-ion batteries systems are being paired with uninterruptible power systems in data centers throughout the world. Experience from those applications combined with fast-improving technology and new safety standards and codes make lithium-ion batteries a highly appealing energy storage solution for infrastructure professionals.

This paper reviews the advantages and disadvantages of LIB compared to VRLA in UPS applications and presents an overview of the codes and standards related to applying LIB safely within the critical infrastructure industry.

We hope to show this is a technology that is proving safe and effective when properly applied.

The following pages address common questions about the use of lithium-ion batteries in the critical space.

Lithium-ion Battery cabinets sit next to a 1200kW UPS

Q. Why the Interest in Lithium-ion Batteries?

Let's briefly review the benefits of using lithium-ion batteries for UPS applications.

First, we must consider the reasons LIB are a natural fit for next generation data centers where IT system operation, availability and space constraints must be balanced with cost.

In general, LIB have a higher energy density, resulting in a 50% to 75% reduction in footprint that can be utilized to add servers and other IT equipment or to reduce facility construction costs. Along with their smaller footprint, lithium-battery systems bring a significant reduction in weight, which can factor into data center design costs.

Lithium-ion batteries also have longer lifespan, which saves on replacement costs and operational disruptions.

Table 1 below offers a brief comparison using relative values:

Advantages of Lithium-Ion Batteries

- Longer effective life
- Greater efficiency
- Higher energy density
- Lower maintenance
- Reduced footprint
- Reduced weight

Summary: Lithium-ion and VRLA (Valve-Regulated Lead-Acid) Technologies

Key characteristic	Lead-acid (vrla)	Lithium-ion
Energy Density	Moderate	High
Lifespan	Medium	Long
Weight	High	Low
Footprint Required	Large	Small-Moderate
Recharge	Moderate	Fast
Maintenance Cost	Moderate	Low
Cooling Required	Moderate	Low-Moderate
Battery Management	Not Applicable	Built-In
Battery Monitoring	Optional	Highly Recommended
Transport Concerns	Flexible	Special Requirements
Disposal/Recycle	Common	Evolving
Upfront Cost	Moderate	High

Lithium-ion batteries offer an effective battery life that is easily double that of a traditional VRLA. This alone reduces the headaches of frequent VRLA battery replacements. LIB are designed with battery management capabilities, including embedded management at the cell, module and cabinet levels. This allows sophisticated data collection of the battery's health to better deliver predictable, consistent and safe performance.

Lithium-ion batteries can operate at higher temperatures without sacrificing battery life. VRLA batteries lose 50% of battery life for every 8°C of heat rise.

Extended life and lower maintenance reduce operational costs, lowering the total cost of ownership (TCO) over VRLA batteries.

Simply put, these batteries are smaller, lighter, longer-lasting and more efficient.

Q. Why Isn't Lithium-Ion Technology Used in More Data Centers?

The cautious adoption of lithium-ion batteries in the data center isn't surprising. First, UL-listed lithium-ion battery assemblies are relatively new and, until recently, the lack of standards kept many data centers from seriously considering them. Because reliability is paramount, the industry tends to go with proven, familiar systems and infrastructure components.

VRLA batteries have long been the standard energy storage solution, yet they have for just as long been the weak link in the power chain. This is because, as every data center professional knows, VRLA batteries are difficult to maintain.

Data center managers, who stake their careers on reliability and uptime, have generally considered VRLA batteries an acceptable risk and a known commodity. Yet, a 2013 study from the Ponemon Institute, commissioned by Vertiv, found UPS and battery failure to be the leading cause of data center downtime.[(1)]

Advances in battery development, coupled with new code standards, are making LIB a more viable choice for data center deployments. As more lithium-ion batteries are used with UPS systems, they are building a history that can better illustrate their value and safety. So, as more organizations evaluate the full picture of their capital decisions, LIB is becoming a compelling choice for many critical facilities.

Bloomberg News Energy Finance estimates lithium will capture 33% market share in the data center by 2025. (June 2017)

Q. What Developments Involve Safety Guidelines for LIB in Larger Industrial Applications?

Numerous standards and testing protocols have been developed to provide direction on how to safely construct and apply lithium-ion batteries (see Table 2).

Underwriters Laboratories (UL) has developed listings for using lithium-ion batteries in UPS applications. The 2018 National Fire Protection Association (NFPA) Fire Code 1 references UL 1973 standard for lithium-ion batteries used in data center applications.

Case in point

Don't Confuse LIB Used in Data Centers With Consumer Level LIB

The safety concerns that have arisen over the past few years regarding lithium-ion batteries largely arose from much smaller batteries used in many consumer devices. This type of LIB uses different materials than those deployed with a UPS. Lithium-ion batteries used in UPS applications also are built with sophisticated safety protections, making them a far cry from the batteries found in consumer electronics.

Why? Because their purpose is entirely different. LIB used in consumer electronics have numerous constraints that do not apply to batteries used in the data center. These include the need for a maximum run time in the smallest possible space, minimal space available for battery management circuitry and minimal space available for thermal management.

The chemistries (see sidebar on page 6) and battery modules used in the data center batteries are designed for safety, not to fit in a cellphone battery compartment. Batteries designed for UPS application have extensive computer-controlled management systems and multi-layered internal safety construction along with far more stringent containment designs. UPS LIB solutions have a fail-safe shutdown mechanism that is activated in the event of a problem.

As the industrial application of lithium-ion batteries has increased, the development of UL standards and other codes and regulations have progressed as well to provide a richer framework for safety. For more than a decade, UL has researched the broad issues that affect the proper operation of LIB to help manufacturers and industry users to better understand the safety aspects of these batteries.

Initial UL LIB testing was conducted for smaller lithium-ion batteries used in consumer applications (see Case in Point "Don't Confuse LIB Used in Data Centers With Consumer LIBs"). Later, UL began testing larger-scale battery systems used in industrial applications such as UPS power storage systems, and automotive applications.

Today, UL has standard testing and qualification processes to verify a safe solution for industrial LIB applications. The individual lithium battery cells are covered under UL 1642.[(2)] UL listing covers both cell construction and the battery management system.

UL 1973, the standard for batteries used in stationary applications, deals with the battery system as a whole. It covers battery cabinet safety and is required by most electrical inspectors and building insurance carriers. This standard outlines a series of safety tests on issues affecting batteries, such as overcharging, short circuit, overdischarge and high temperature.

These standards and testing protocols entail product safety tests to assess a battery's ability to withstand certain types of abuse.

Safe transport of LIB engendered additional standards. UN (United Nations) 3480 and 3481 cover transportation safety testing for all lithium metal and lithium-ion cells and batteries. The protocols have yielded eight different tests focused on transportation hazards.

Q. What are the Associations and Governing Bodies Doing?

An essential part of the LIB safety standard story is the NFPA (National Fire Protection Association) code. In the recent 2018 NFPA code update,[3] the location where the lithium-ion batteries are installed is a key part of these new guidelines. Batteries must be housed in a UL-listed, noncombustible locked cabinet. There are also restrictions on floor location and rooftop installations.

The 2018 NFPA Fire Code 1 has a five-page section (Section 52.3) on how to safely deploy LIB for data centers and other applications. These requirements affect lithium-ion systems that exceed 20kWh, which for a typical application corresponds to 40 amp-hour for a 200W rated battery, or 5 minute 50kW UPS load.

The guidelines set the maximum number of batteries within certain types of areas. A hazard mitigation analysis, such as a failure mode and effects analysis (FMEA), must be performed in some situations. The level of safety required can depend on factors such as the installed battery.

The code requires that batteries have UL 1973 listing and mandates that an approved battery management system (BMS) must be used for monitoring and balancing cell voltages, currents, charge cycles and temperatures within the manufacturer's specifications. The LIB and BMS must come as a package from the OEM.

Fire suppression is also mandated. Rooms containing stationary storage batteries are required to be protected by an automatic sprinkler system. An approved automatic smoke detection system must also be installed in rooms containing these batteries.

While there are no gas emission or chemical reactions between electrolyte and electrodes during normal charging/ discharging of LIB, the NFPA states that, where required, ventilation shall be provided for rooms and cabinets in accordance with the applicable codes. Over-heating protection is also required to detect, control and prevent any over-temperature conditions of lithium-Ion batteries used in these applications.

Governing Body	Code	Purpose
UL	UL 1642	Lithium Batteries
UL	UL 1973	Batteries for Use in Light Electric Rail (LER) Applications and Stationary Applications
UL	UL 2054	Household and Commercial Batteries
NEC	Article 706	Energy Storage Systems
IEC	IEC 62619	Stationary Energy Storage Systems with Lithium Batteries
IEC	IEC 62897	Safety Requirements for Secondary Lithium Cells and Batteries for Use in Industrial Applications
NFPA	Fire Code 1	Deploying Lithium Batteries

Table 2

Q. So What Makes LIB Safety Within the UPS Applications Better?

The chemical composition of LIB's used with a UPS are less heat-sensitive than those found in consumer-level batteries (see Case in Point sidebar on safety). Additionally, they are typically installed in larger operating areas, have more robust packaging, and are applied in less-stressed user environments.

Leading LIB manufacturers utilize highly developed quality and safety features aimed at minimizing the chance of thermal runaway. Safety fuses, overcharge protection, hardened material layers and thermal dissipation measures are but a few of the built-in safety advances. The battery monitoring and management capabilities add to the performance and safety.

A BMS used in a UPS application generally consists of two levels. One monitors voltage, temperature and current at the cell-level. This information is sent up to the second level, a rack-level controller that manages the safety functions at a system level. The rack-level BMS can relay how the battery is performing and report data that enables managers to accurately gauge the battery system's health. In addition, the BMS can manage the battery system through cell balancing and switching control.

Any remaining safety issues that surround the utilization of commercial LIB in critical spaces can be effectively minimized. Combining the proper chemical makeup with advanced construction techniques and new safety and installation standards, an LIB system can leverage higher energy densities while providing a beneficial energy storage solution for vital data center environments.

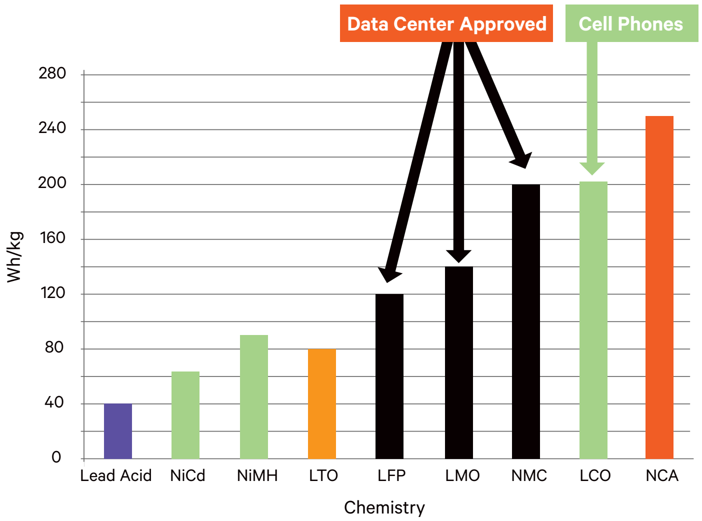

Figure 1

Case in point

Safety: Pick the Right Chemistry for the Application

There are numerous variations of lithium-ion batteries due in part to the different pairing of compounds within the battery. Each performs differently (see Figure 1).

Handheld electronics typically use batteries based on lithium cobalt oxide (LCO), which offers high energy density but presents stability risks, especially when damaged.

Lithium nickel manganese cobalt oxide (NMC), lithium iron phosphate (LFP), and lithium manganese oxide (LMO) batteries offer somewhat lower energy density, but longer life and are inherently safer than LCO.

Lithium-ion batteries do not contain mercury, lead, cadmium or any other material considered to be hazardous.

A good reference is IEEE 1679.1-2017 Guide for the Characterization and Evaluation of Lithium-Based Batteries in Stationary Applications.[4]

Building Management System and Facility Monitoring Capabilities

Vertiv has leveraged its industry-leading battery monitoring and predictive analysis expertise to interface with lithium-ion batteries. The company offers several system level monitoring solutions that can be used with LIB in data center UPS applications.

Battery management can extend to the facility through many building management systems (protocols such as Modbus). This can provide a single battery monitoring dashboard that can aggregate multiple lithium-ion battery manufacturers' data into a common interface.

Monitoring of lithium-ion, lead acid and Ni-Cad batteries can be combined into that same common interface, so users need not worry about the consequences of having multiple battery technologies across their operations.

Using LIB with the UPS?

It is important to utilize only LIB battery systems supported by the manufacturer of the UPS system. The characteristics of LIB technology used with a UPS are different than with a traditional VRLA battery system and compatibility must be ensured. Data center operators should work with a UPS supplier who understands the installation, safety and maintenance aspects of these power storage systems in critical IT facilities. Installation, startup, commissioning and monitoring should be performed by experts who are trained and qualified to work with lithium-ion systems. Vertiv customers are benefiting from the company's experience in using LIB with their UPS systems since 2011.

Lithium-ion batteries are not maintenance-free in critical systems applications. Though less maintenance is required than with VRLA batteries, LIB still demand proper inspection and care throughout the life of the battery system.

Typical preventive maintenance plans should follow the manufacturer's guidelines, include a review of battery logs, and provide a report of the findings. A leading service organization should offer the appropriate blend of onsite and remote monitoring, customized for LIB to ensure performance is maintained.

Conclusion

The benefits of lithium-ion battery technology for UPS applications are many, but they require some different procedures and protocols than VRLA batteries. The safe operation of a UPS system that incorporates LIB, however, can be assured by following the established guidelines and processes.

Effective chemistry decisions and battery construction practices have improved LIB safety, making them reliable alternatives to VRLA. Today's lithium-ion batteries are proving themselves safe, reliable alternatives to VRLA with a compelling TCO case.

References

[1] 2013 Cost of Data Center Outages — Ponemon Institute

[2] Safety Issues for Lithium-Ion Batteries — Underwriters Laboratories

[3] NFPA Code — 2018

[4] IEEE Std 1679.1-2017

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