VERTIV WHITE PAPER

The Advantages of Using Lithium-Ion Batteries in Single-Phase UPS Applications for Edge Data Centers

How Branch Offices, Server Rooms, and Network Closets Can Benefit from Using Lithium-Ion Battery Systems

Executive Summary

Lithium-ion batteries are a common energy storage source for millions of consumer devices and electric vehicles. They are now also increasingly being used with Uninterruptible Power Supply (UPS) applications to ensure uptime for mission-critical infrastructures in data centers. For companies wishing to deploy distributed computing and edge networks, lithium-ion batteries are ideal for use with IT deployments in remote locations. Lithium-ion batteries require less maintenance and have a higher power density than lead-acid batteries. Lithium-ion batteries last 2-3 times longer than lead-acid batteries, resulting in fewer battery replacements and lower TCO. Also, lithium-ion batteries include a Battery Monitoring System (BMS) and other features that help to ensure safe battery operation. While the initial cost of lithium-ion batteries is still moderately higher than lead-acid batteries, this difference is shrinking. Lithium-ion batteries can now provide a lower total cost of ownership (TCO) than lead acid batteries in less than five years. Over the typical service life of a UPS, a lithium-ion battery system can provide savings of 40% or more.

Introduction

Whether you are a financial or retail company looking to set up IT deployments at branch offices or store locations or a healthcare organization deploying IT footprints on hospital campuses over a wide geographic range, your company is investing in a distributed computing or edge network. Often these small data centers, server rooms, and network closets rely on a single-phase UPS to power their IT infrastructure, as opposed to a three-phase UPS typical of larger IT installations. Like their three-phase counterparts, single-phase UPS systems require a reliable stored energy source. Backup battery systems for edge-of-network installations need to operate correctly at the crucial moment when the UPS must deliver backup power to the load. Over the past five years, lithium-ion batteries have become a more popular choice as a stored energy source in traditional data centers. In this white paper, we'll look at how these types of batteries can also be used to support single-phase UPS systems in remote mission-critical environments and edge data centers.

The Purpose of UPS Batteries — Traditional vs. Remote Data Centers

In traditional data centers, the battery system is an essential fail-safe device. In the event of a power outage, strings of batteries provide power to the UPS during the several minutes of ride-through time in which the data center switches over to an auxiliary power source, such as a second utility feed or generator.

But in edge data centers or remote IT deployments, the function of the battery may be slightly different. In many cases, the battery system is that facility's auxiliary power source. The batteries may provide backup power to the UPS for 30 minutes or more if a power outage occurs. Without alternative power capability, these remote sites rely on stored energy from the UPS batteries to provide adequate time for the utility to be restored, for IT administrators to migrate virtual IT environments to stable sites, or for the operating systems to conduct an automatically controlled power shutdown of connected equipment.

In either case, the battery system's purpose for traditional or remote data centers is the same. The battery helps to ensure uptime by keeping the IT infrastructure operational. As such, a traditional, remote, or edge facility must have a reliable battery system to ensure continuous operation of the UPS and ongoing IT equipment availability.

The Drawbacks of Lead Acid Batteries

Until recently, lead acid batteries were the go-to source for storing energy for UPS applications.

The most common types of batteries used in data centers are Valve-Regulated Lead Acid batteries or VLRAs.

But lead acid batteries have drawbacks that make them risky and expensive to use in data centers. Most data center owners and engineers will tell you that lead-acid batteries are the weakest link in their power distribution chain. They are the element that is most likely to fail at the moment when they are most needed.

It's hard enough to deploy and manage lead-acid batteries in traditional facilities. But when VRLA batteries are used in remote facilities and edge data centers, these same drawbacks produce a new set of problems that increase the trouble and cost of using them. The drawbacks include:

Unreliable Performance

UPS units are powered by strings of lead-acid batteries, in which any individual battery can be a point of failure. If just one battery fails, it can bring down the data center's entire UPS system.

A 2013 study by the Ponemon Research Institute found that 55% of unplanned data center outages and one-third of all UPS system failures were due to the failure of VRLA batteries.

Root Causes of Unplanned Downtime

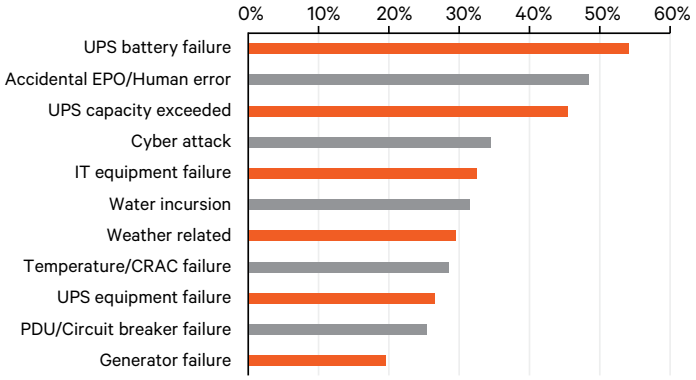

***Figure 1:** Over 50% of Unplanned Outages Caused by Battery Failure (2013 Ponemon Study)*

Short Life

Lead acid batteries must be replaced every 3-5 years. Their useful service life is determined by how often the batteries are discharged and recharged. But factors such as overcharging, frequent discharge cycles, strained battery terminals, loose connections, and higher ambient temperatures in the facility can shorten the battery's useful life.

When the battery reaches 80% capacity, it is considered end of life (EOL). Performance degradation typically accelerates at this point and the battery loses its ability to provide sufficient voltage.

As seen in Figure 2, after three years of use, the VRLA battery's capacity begins to drop off. This drop becomes even steeper after five years of use. Older batteries may be vulnerable to "sudden death syndrome, " in which a battery works fine one day but fails to provide sufficient power the next day, resulting in a UPS failure and data center downtime.

Typical VRLA Battery Capacity over Time

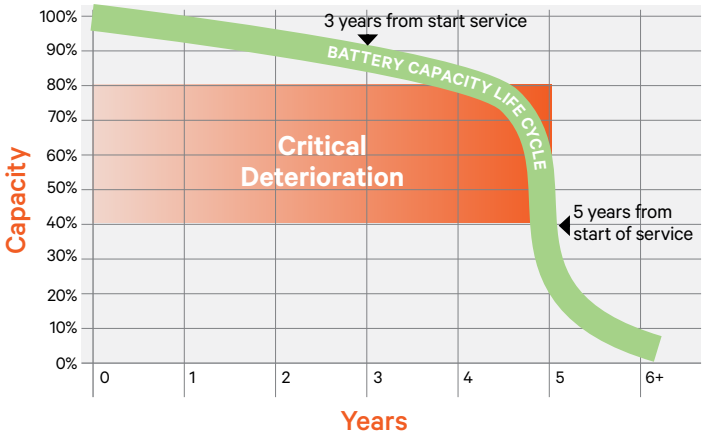

Figure 2

Size and Weight

Lead acid batteries require valuable rack space that might otherwise be used for IT infrastructure. This is a problem in any IT environment, but especially in small, remote facilities such as server rooms, network closets, and containerized units, where space for IT servers is even more limited. Also, lead acid batteries are heavy and difficult to move, which adds to the labor time and cost of installing or replacing the batteries in remote facilities.

Temperature Sensitivity

The battery's useful life is strongly affected by the battery's operating temperature, even if the battery is not experiencing charging and discharging cycles. With lead acid batteries, a controlled room temperature of 77˚F (25˚C) is necessary, to ensure a 3–5 year lifespan. With every 15˚C increase in room temperature, the useful life of a typical VRLA battery is cut in half.

The Different Types of Lithium Batteries

Lithium-ion batteries have many uses, but not all lithium-ion batteries are the same. Table 1 below shows the different types of chemistries used in lithium-ion batteries, and the applications for each type of battery.

Chemistry	Lithium Cobalt Oxide	Lithium Manganese Oxide	Lithium Nickel Manganese Cobalt Oxide	Lithium Iron Phosphate	Lithium Nickel Cobalt Aluminum Oxide	Lithium Titanate
Short Form	Li-cobalt	Li-manganese	NMC	Li-phosphate	Li-aluminum	Li-titanate
Abbreviation	LiCoC2 (LCO)	LiMn2O4 (LMO)	LiNiMnCoO2 (NMC)	LiFePo4 (LFP)	LiNiCoAlO2 (NCA)	Li2TiO3 (LTO)
Comments	High energy, limited power. Market share in decline	High power, less capacity; safer than Li-cobalt; often mixed with NMC to improve performance	High capacity and high power	Flat discharge voltage, high power low capacity, and safe; elevated self-discharge	Highest capacity with moderate power. Similar to Li-cobalt	Long life, fast charge, wide temperature range and very safe. Low capacity, expensive
Common Uses	Mobile consumer devices, such as laptops, smartphones, and digital cameras	Medical devices, power tools, consumer devices, electric vehicles	Electric vehicle powertrains, cordless power tools, electrical grid storage	Stored energy for mission-critical environments. Also used in electric vehicles	Electric vehicles	Electrical grid storage

Table 1: *Attributes of Lithium Battery Chemistries*

Lithium-Ion Batteries for UPS Applications

Manufacturers have developed lithium-ion battery solutions for specific use with UPS applications within the past five years. Lithium-ion batteries have become a viable alternative source of stored energy, due to their improved performance, the flexibility of use, and reduced TCO over lead acid batteries.

The lithium battery chemistries used in UPS applications are lithium iron phosphate (LiFePO4, or “LFP” for short), lithium manganese oxide (LiMnO2 or “MO”), and lithium nickel manganese oxide (LiNiMnCoO2, or “NMC”). There is also a UPS battery that uses an LMO/NMC blend to improve performance.

(NOTE: for an in-depth look at the properties of the LFP, LMT, and NMC chemistries, see the Vertiv application report, "The Emergence of Lithium-Ion Batteries Within the Data Center.")

Advantages of Lithium-Ion Batteries

Improved Reliability and Availability

The manufacturers of lithium-ion batteries that are qualified for UPS applications utilize improved battery design, quality materials, and superior manufacturing methods. With a longer lifespan and reduced maintenance requirements, the failure of lithium-ion batteries in mission-critical environments is extremely rare.

Also, all lithium-ion batteries include a built-in battery management system (BMS), which provides fault monitoring, cell balancing, and power optimization capabilities for each individual battery. The BMS helps to maximize battery life and minimize downtime.

Longer Lifespan

Lithium-ion batteries typically have a design life of 8-10 years, which means they should have the same lifespan as a single-phase UPS. When a VRLA battery is at 80% capacity or EOL, the lithium-ion battery is still at 93% capacity. The longer life span adds up to significant cost savings. Also, lithium-ion batteries can be fully charged and stored for greater lengths of time than VRLA batteries, with minimal impact on the battery's lifespan.

Lower Weight

Lithium-ion batteries weigh about 60% less than lead-acid batteries. This makes the batteries easier to transport and install in remote facilities.

Smaller Footprint

Lithium-ion batteries can be up to 70% more compact than lead-acid batteries. This provides space savings in any on-site or remote facility, increasing available rack space for IT servers and networking equipment.

Higher Energy Density and Power Density

Lithium-ion batteries have a higher energy density (Wh/kg, or watt-hours per kilogram) and power density (W/kg, or watts per kilogram). They offer the same amount of energy as lead acid batteries but with a smaller size and lower weight.

Accommodate Higher Temperatures

Lithium-ion batteries for UPS applications are designed to operate at higher temperatures than lead-acid batteries. Most lithium-ion batteries can operate at temperatures of 86˚F (30˚C) –almost 10 degrees higher than lead acid batteries – without degradation or reducing calendar life. This allows for increased room temperatures in data centers or remote server rooms, which lowers cooling costs.

Faster Recharge

Lithium-ion batteries can typically be recharged to 90% capacity in under 2 hours for rack-based systems, whereas VRLA batteries may take more than 4 hours to reach the same level and up to 24 hours to recharge fully If the data center has several outages in short succession, the lithium-ion battery can recharge fast enough to provide ride-through time for each outage.

Reduced Operating Costs = Lower TCO

Until recently, the high initial cost of lithium-ion batteries hindered their adoption for UPS applications. Today, the initial capital investment for a lithium-ion battery system for remote facilities or edge data centers is, on average, between 1.75x and 2.25x the cost of a VRLA battery system for these same facilities. Additional price reductions are expected over the next decade as lithium-ion batteries come into more widespread use in data centers.

Compared to VRLA batteries, lithium-ion batteries offer long-term savings for data center owners in reduced operating costs, resulting in a lower TCO. As mentioned, lithium-ion batteries have an estimated design lifespan of 8-10 years, which may equal that of your single-phase UPS. This eliminates the cost of replacing lead acid batteries every 3-5 years and the shipping, travel, and labor costs required to replace VRLA batteries in remote data centers.

A recent evaluation test by Vertiv compared the TCO of lead-acid and lithium-ion batteries used in single-phase UPS applications. The cost comparison looked at initial cost and battery replacement costs from various leading manufacturers over a 10-year timespan for VRLA and an industry leader for lithium-ion batteries.

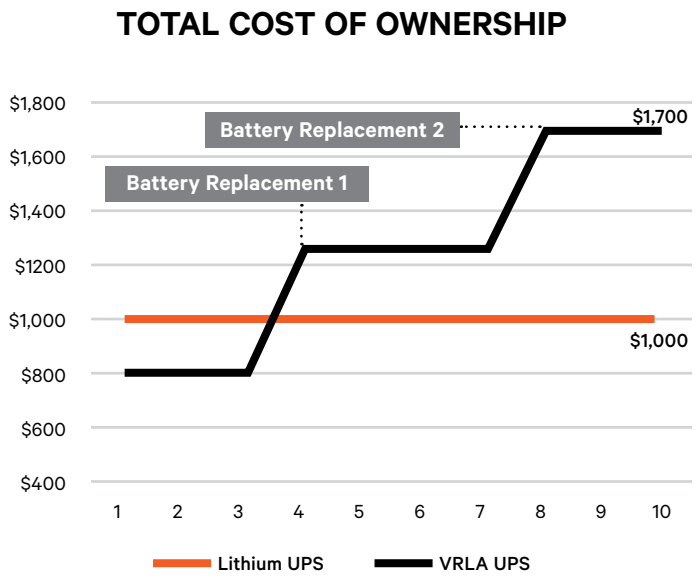

Figure 3: *Lead Acid vs. Lithium-Ion Batteries – TCO Comparison*

As seen in Figure 3, the study revealed that while the initial costs of VRLA systems are lower, the operating costs increase steadily over the 10-year lifespan of the UPS, with significant cost increases each time VRLA batteries must be replaced. By contrast, while the initial costs of a lithium-ion battery system are higher, the overall costs remain relatively steady over this same 10-year period. The lithium battery system shows a return on investment (ROI) within five years, beginning after the first VRLA replacement cycle. In relative dollars, the lithium battery system is more cost-effective over the long run.

Table 2 below provides the data that was used in this cost comparison.

	1500VA Lithium-ion UPS	1500VA VRLA UPS
Year 0		
UPS Average Price (single-phase UPS comes with an internal battery)	$1,000	$800
Year 3-4		
Replacement Battery		$250
Labor		$200
Year 6-8		
Replacement Battery		$250
Labor		$200
10-year TCO	**$1,000**	**$1,700**
TCO Savings	**41% or $700**	

Table 2: *Lithium-Ion vs. Lead Acid Batteries – 10-Year TCO Comparison Data*

Over the 10-year lifespan, the UPS with a lithium-ion battery does not require battery replacement. Therefore, although the initial cost of the lithium battery system is higher, after ten years, using lithium-ion batteries results in TCO savings of $700, or 41%.

Are Lithium Batteries Safe?

Yes. Lithium battery solutions that are used in UPS applications have a BMS that monitors critical parameters (such as temperature, voltage, and current) at the cell level, ensuring safe and reliable operation throughout the life of the system.

All types of batteries are vulnerable to a condition known as thermal runaway. This occurs when the chemistry inside a battery cell reaches such a high temperature that it exceeds its ability to disperse heat, resulting in a failure.

However, for the lithium chemistries used in UPS applications, the thermal runaway temperatures are higher than 200˚C (400˚F). Most lithium-ion batteries have a control temperature limit of around 70˚C (158˚F) due to life considerations. When the battery reaches this control temperature limit, the Battery Management System will automatically disconnect the battery from the UPS load or charger.

Lithium-ion batteries for UPS systems include safety fuses, overcharge protection, and hardened material layers and are manufactured in compliance with UL and other applicable safety standards.

Conclusion

The cost analysis and performance data clearly show why lithium-ion batteries are the better stored energy source for single-phase UPS systems. Over a 10-year UPS lifespan, lithium-ion batteries provide significant TCO savings without the inconvenience and cost of replacing lead acid batteries. The longer lifespan and reduced maintenance needs of lithium-ion batteries produce a significant ROI in less than five years.

Lithium-ion batteries' smaller size and reduced weight provide better flexibility for use in remote facilities. And with superior performance, lithium-ion batteries can help to ensure uptime and continuous operations for IT deployments. The combined advantages in cost-effectiveness, performance, and safety will be well worth the initial investment, as lithium-ion batteries will provide dependable long-term service to your mission -critical IT infrastructure in server rooms, network closets, and edge data centers.

To learn more about how lithium-ion battery solutions can be used with UPS applications in remote facilities and edge data centers, visit Vertiv.com

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