Assessing and Selecting a Lithium-Ion UPS Solution

Overview

Industrial rack-mounted Uninterruptible Power Supplies (UPS) are used in data centers or telecom central offices to provide backup power for servers and switching equipment in the event of failure. Historically, these UPS's have relied on Lead Acid as the predominant battery type. With the introduction of the Open Compute Project (OCP) initiative and hyperscale data centers, Lithium-ion batteries are gaining market share over the incumbent Lead Acid battery technology.

This article presents some of the fundamental considerations and trade-offs when selecting a Lithium-ion UPS system to complement your data center equipment. Several critical considerations include the available chemistry options of Lithium Iron Phosphate (LFP) versus Lithium Nickel Manganese Cobalt Oxide (NMC), expected discharge time, active versus passive cooling, options for scalability, and the ability to support peak shaving as a secondary function.

Two Practical Lithium Chemistries for UPS's

For typical UPS applications, there are two popular Lithium-ion chemistry variants offered by UPS vendors. Lithium Nickel Manganese Cobalt Oxide (NMC) is the most common Lithium chemistry in the world, as it is predominantly used in notebooks and cell phones for example. Lithium Iron Phosphate (LFP) is less common in consumer applications, but is used in high cycle life or high-power applications such as power drills or industrial electric vehicles (buses, forklifts).

LFP VS. NMC

Parameter	Lithium Iron Phosphate (LFP)	Nickel Manganese Cobalt (NMC)	Comparison
Voltage	3.2 V	3.7 V	NMC Batteries are lighter and more compact
Weight Energy Density	90-120 Wh/Kg	150-250 Wh/Kg	
Volume Energy Density	300-350 Wh/L	500-700 Wh/L	
Max Discharge Rate	30C	2C	LFP Batteries provide more power over a shorter period, and can be charged faster
Max Charge Rate	10C	0.5C	
Typical Cycle Life (@80%)	3000+ Cycles	500-1000 Cycles	LFP Batteries will deliver more cycles over a longer calendar life
Calendar Life (@80%)	8+ Years	3~ 4 Years	
Thermal Runaway Onset*	~195 °C	~170 °C	NMC Batteries have lower thermal runaway thresholds and will burn hotter
Thermal Runaway Increase*	210 °C	500 °C	

* Royal Society of Chemistry, 2014

A comparison of LFP and NMC battery chemistries

As detailed in Image 1, NMC chemistry has a higher weight and volume energy/density ratio than the competing LFP chemistry. Additionally, NMC chemistry has a lower cost/Watt-Hour than LFP. As a result, the higher energy density and lower cost makes NMC the optimal chemistry for most lower power consumer applications. This means that, given a certain volumetric space allowance for the UPS, an NMC-based UPS will deliver more run-time than the comparably sized LFP-based UPS.

Life Expectancy and Safety

Three main dimensions affect the longevity of a Lithium-ion battery – number of cycles, the length of time in service, and the ambient temperature of the operating environment. Industry norms measure the effectiveness of a battery by comparing the actual capacity relative to the original capacity of a fresh battery. LFP Batteries deliver at least 2000 – 3000 full charge/discharge cycles before reaching 80% of their original capacity. Typical NMC batteries deliver 500 – 1000 full charge/discharge cycles before reaching 80% of their original capacity. This means that LFP batteries provide 2-to-3 times more cycle life than typical NMC batteries. While the calendar life of an NMC battery is 3-to-4 years, the calendar life for a LFP battery typically exceeds 8 years. The selection of NMC and LFP chemistry will affect the useful life of a UPS.

LFP Batteries have an intrinsically safer cathode material than NMC batteries and do not decompose at higher temperatures. In effect, LFP batteries provide the best thermal and chemical stability, which results in superior safety over NMC batteries. As detailed in Image 1, a LFP battery will only enter a thermal runaway condition at 195 Celsius and release minimal energy during thermal runaway. A typical NMC battery can enter thermal runaway condition as low as 170 Celsius, and will release more energy and burn at a much hotter temperature. All Li-ion batteries are safe, but LFP is one of the safest Lithium-ion battery chemistry available.

Current Delivery and Expected Run-time

In general, there are two typical modalities or use models for UPS solutions. The first application is when the data center operator plans to use the UPS for a 5-to-10-minute interval, specifically, the interim period from power loss until the back-up generator is started. In this scenario, the UPS is sized to deliver all available energy at a very high rate. The second application is when the data center operator plans to use the UPS for a 1-to-8 hour discharge, and wishes to avoid starting the backup generator until it is absolutely required. In this application, the UPS is the primary source of power for a much longer period.

An LFP battery can deliver (and receive) more current that a similar-sized NMC battery. As an example, a 48 Volt 50 Amp-Hr NMC battery (2400 Watt-Hr) can deliver around 50-100 Amps, while a similar-sized LFP battery can deliver around 500-1000 Amps. The power delivery is a critical factor in the UPS configuration. To deliver a specific amperage profile, multiple NMC batteries may need to be connected in parallel to reach the needed Amps, while a single LFP battery may deliver the required Amps. Given a specific space constraint, this means that a NMC battery is more appropriate for applications that can tolerate lower current delivery over a longer discharge period (i.e., 50 Amps over one hour), while LFP can also accommodate a higher current delivery over a shorter discharge period (i.e. 300 Amps over 10 minutes). The expectation for back-up runtime is a critical factor in selecting the battery chemistry.

Passive or Active Cooling

If you survey the market of rack-mounted UPS's, you will notice that there is a variety of options for thermal management, ranging from passive cooling (no fans) to active cooling (continuously running fans) to dynamic active cooling (variable rate fans driven by internal battery temperature). The third dimension that affects the longevity of Lithium-ion batteries is the ambient temperature. Lithium-ion batteries can safely operate between -20 and +60 Celsius, but the optimal temperature range to maximize the battery life is between 10 and 30 Celsius. High current discharges will create internal heating within the cell, but a stable temperature environment maximizes the battery's life.

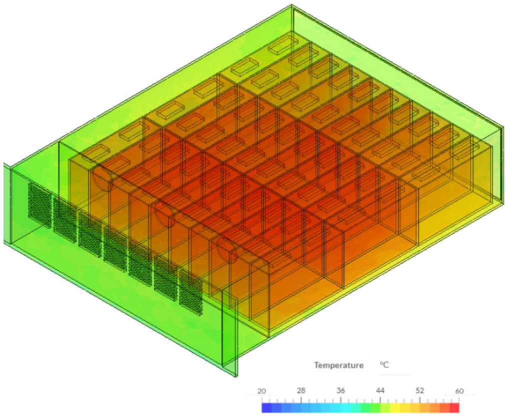

Image 2: 150 Amps discharge without active cooling reaches 60 Celsius

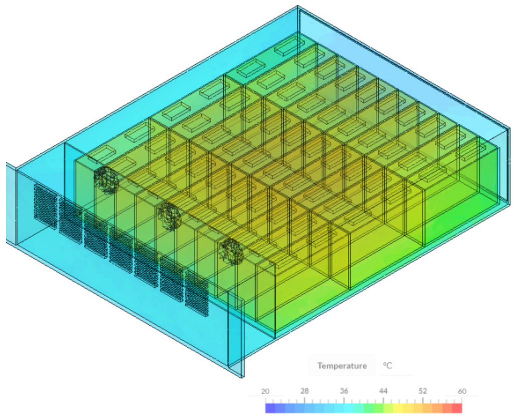

Image 3: 150 Amp discharge rate with active cooling reaches 50 Celsius

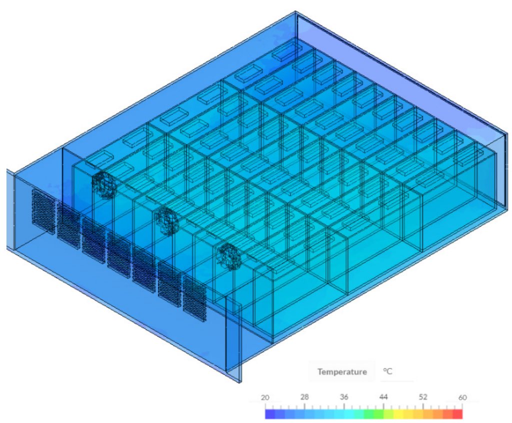

Image 4: 50 Amp discharge rate with active cooling reaches 33 Celsius

Images 2, 3 and 4 demonstrate the impact of active cooling with fans on a UPS battery. The thermal images are modeling a 48 Volt 100 Amp-Hr NMC battery (4800 Watt-Hr), and they show the surface temperature of the Lithium-ion cells contained with the UPS. In Image 2, the UPS is continuously discharging at 150 Amps (1.5C rate) without any active cooling. The peak temperature of the cells is around 60 C, which is close to the safety cut-off limit imposed by the UPS electronics. Then, in Image 3, active cooling is applied through the UPS enclosure while the battery is delivering 150 Amps, and the peak temperature of the cells drops to around 50 C, noticeably cooler and safely below the cut-off limit. To demonstrate the effects of discharge rates and current delivery on the UPS, Image 4 shows the UPS discharging at 50 Amps (0.5 C rate) with active cooling. The cells are noticeably cooler than the UPS delivering 150 Amps with active cooling. Note that based on the chemical composition and higher impedance of NMC cells, they will generate more heat when discharging compared to LFP cells. Given that heat abatement is a critical issue within data centers, the chemical composition of LFP cells does give it an advantage in climate-controlled environments.

Basic Backup, or Upgrade to Peak Shaving?

In certain countries and states/provinces, the electric utility may implement Time-of-Use (ToU) pricing policies to level out the power demand between the day and night periods. During times of high demand for electricity (i.e., weekdays), utilities charge a premium peak utility rate for power. Off-peak pricing goes into effect when there is excess power available for residential and industrial customers (i.e., evenings and weekends).

With on-premise energy storage, the batteries are charged whenever electricity rates are at their lowest. Then the same batteries are discharged during peak hours to complement the primary grid power, therefore minimizing power consumption during peak pricing periods. The price differential is large enough to drive consumer behavior to shift their time of power consumption. A slightly different variation of this configuration is charging the batteries with solar power during the day, and that stored energy powers equipment in the evening or the following day during peak pricing periods.

Rack-mounted UPS's are typically used by data centers for traditional battery back-up functions, but there is heightened interest in using UPS's in peak shaving applications. The primary difference is the basic back-up application discharges the batteries occasionally during power outages. Both NMC and LFP batteries can support these occasional discharge/charge cycles. The useful life of the UPS will be determined by the calendar life of the chemistry, as mentioned earlier. NMC will experience a shorter 3-to-4 year calendar life, while LFP delivers a longer eight-plus year calendar life. When the batteries are discharged/charged on a daily basis, this higher use application starts to favor LFP chemistry since it can support many more cycles than NMC throughout its useful life.

Product Scalability

Another dimension to consider is the level of scalability the UPS product line offers. Depending on the equipment supported by the UPS, the equipment may need 100 Amp-Hrs or thousands of Amp-Hrs of capacity and run-time. Scalability of a UPS system can be achieved through several methods. First, the manufacturer may offer various models that support different tiers of battery capacity. Models are typically configured in 19/21/23-inch wide models, depending on the rack used to hold the UPS. The manufacture may offer different height models, typically measured in Rack-Unit (RU) or Unit (U) increments. Maximum flexibility is achieved with a range of products that provide a selection of 1, 2, and 4 U high products. This enables the data center operator to select the optimal amount of power without overpaying for unwanted battery capacity.

More importantly, the other dimension of scalability is the ability to connect the UPS's in parallel (electrically) so individual modules can operate as one uniform, larger battery. If the desired run-time exceeds the capacity of the largest module offered by the manufacturer, then connecting the modules in parallel enables scalability to any capacity, regardless of the capacity limitations of the individual modules. These connected modules create a battery array that can be charged and discharged as a common unit, and extend your run-time to the desired duration. Some UPS products are stand-alone units that cannot be connected in parallel, while other products allow parallel connection up to specific Amp-Hr or Watt-Hr limits. Creating a larger array with modules is not only common for data center UPS applications. This technique is also used in other energy storage applications such as commercial solar farms, wind farms, cellular infrastructure, and micro-grids.

In summary, there are many rack-mount UPS solutions available on the market. Before selecting a manufacturer or model, you should perform a power study on your data center equipment to assess the power needed to sustain operations during a power loss, and then determine the duration that the UPS must power the equipment. Armed with this data, you can assess critical features like the Lithium-ion battery chemistry, passive and active cooling features, and level of scalability offered by available solutions. Once you have factored these features into your selection criteria, the subsequent list of viable manufacturers and UPS models will ensure the selected UPS provides the needed power during outages. To best serve the market and the wide variety of applications

Green Cubes manufactures both a NMC and LFP solution for Telecom and Datacom Energy Storage. Please contact us today to discuss your application.

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Harnessing our 35 years of industry experience, Green Cubes Technology is committed to designing, manufacturing, and implementing Lithium-ion platforms that give you The Power to Perform. Our battery packs are sustainable, maintenance-free, environmentally friendly, and superior performing.

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