Lithium-ion In the Data Center

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In this whitepaper, we explore the advantages of lithium-ion UPS battery technology over lead acid in the data center environment.

ABSTRACT

Lithium-ion batteries offer several improvements over lead acid batteries, including reduced capacity degradation, high cycle life, and high operating temperature. Data centers and data closets reliant upon an aging or unreliable grid will benefit in particular from these characteristics.

Methode has collected data from both a lead-acid and a lithium-ion UPS to further illustrate the benefits.

INTRODUCTION

The data center environment, be it a mammoth facility owned and operated by a single entity or a two-post rack next to the broom closet in the local branch of a bank, is constantly evolving. Of the myriad equipment and configuration choices available to data center managers, one of the more commoditized assets is an uninterruptible power supply (UPS). A unit is selected, often at the direction of a qualified re-seller, a service contract is purchased, and it runs along silently for three-to-five years. The batteries will be replaced along the way, but the user interface and power electronics all operate without incident. As long as the batteries are not cycled often, this is a reasonable arrangement.

However, several factors are coming into play that makes this assumption and acceptance of short cycle life a poor business decision. The grid and related infrastructure in the United States is aging and often over capacity. Americans experienced 285% more power outages in 2014 than in 1984, all while increasing our reliance upon digital connectivity to do even the most basic business task.[1] In addition, changing weather patterns—like the snow storm on the Texas-Mexico border in December 2015—expose vulnerabilities in the infrastructure. A staggering 85% of the outages reported in 2014 were weather-related, many of which are in data center hotbeds like California, New York and Washington.

To address this convergence of both battery and infrastructure reliability, many companies are looking for other solutions. Large corporations are deploying flywheels and even experimenting with fuel cells. However, for a more traditional deployment (and capex strategy), lithium-ion batteries offer a viable alternative to traditional lead-acid solutions

CAPACITY DEGRADATION

Throughout the majority of its life, a UPS is ignored. Its primary purpose is to sit in stand-by or high-efficiency mode and pass power seamlessly to downstream equipment. When the power does go out, however, it is crucial to be able to rely upon a UPS to perform as expected. One manner in which lead acid fails to meet expectations is through capacity degradation.

All batteries will experience capacity degradation, as the cathode within the battery cell erodes from repeated charge/discharge cycles. The rate at which a battery sheds capacity becomes crucial from a planning perspective, as an unanticipated decrease in runtime could be the difference between troubleshooting an outage and corrupting file servers.

To quantify this capacity degradation of the two battery types, long-term cycle testing was performed. A new APC SUA5000RMT5U lead acid UPS and a new Methode AC6000 lithium-ion UPS were fully discharged in a 23°C lab. Both units were run into rectifiers not unlike the front-end power supplies in a typical server; the rectifiers were connected to a constant-current DC load set to draw the maximum nameplate power of each device.

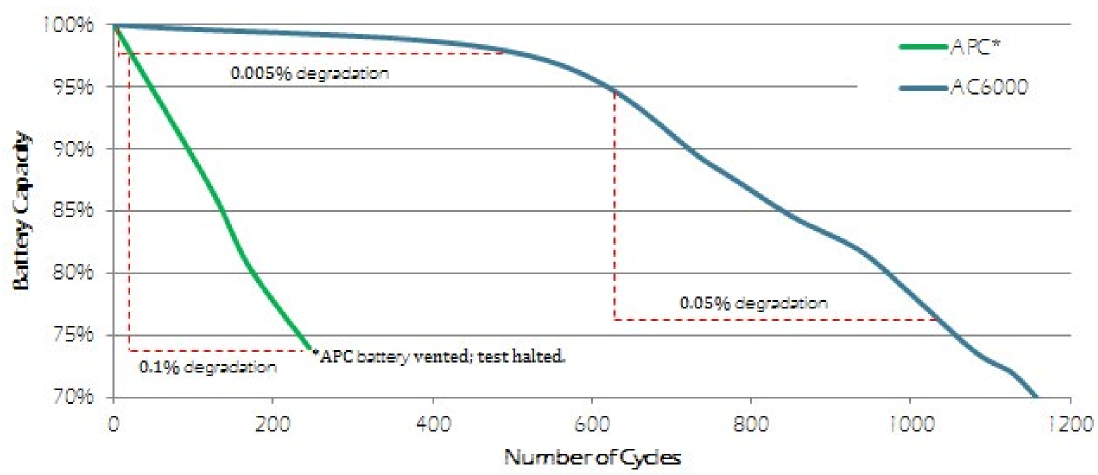
Initial conditions and cycle profile are outlined in the table below.

Nameplate Specifications	Methode AC6000	APC SUA5000RMT5U
100% Load Runtime (min)	6:00	9:00
Output Power (kW)	6.0	4.0
Charge/Discharge Cycle (h:mm)	1:45/0:15	3:45/0:15

The units were charged and discharged continuously until each reached 70% of the original runtime, with ample buffer time provided during charge to ensure top-of-charge was attained. The APC reached this threshold in 265 cycles, while the Methode ran for 1,164 cycles.

CYCLE LIFE

It is not reasonable to consider capacity degradation as a standalone criterion for UPS selection; cycle life of the battery must also be taken into account. For example, if the APC model referenced above were deployed downstream from a very stable grid, in all likelihood the battery may never be cycled with enough frequency to approach this degradation. However, with ever-increasing reliability issues in the American power infrastructure, the need for a trustworthy back-up power supply becomes more crucial. The figure below illustrates the cycle life of a lead-acid and lithium-ion UPS.



In addition to higher cycle life and improved capacity retention, it is worth noting the manner in which capacity degrades in each unit. The lead-acid battery capacity falls off in a rather precipitous linear fashion, making it predictable, if not reliable. The lithium-ion battery maintains capacity above 98% for over 500 cycles, degrading at a rate that is one-twentieth that of the lead acid unit. It should also be noted that the APC could not be taken to 30% capacity reduction as the batteries vented, a failure indicated by a drastic drop in run-time (24% of original) and the release of noxious gas into the lab.

Practically speaking, there are positive implications for even the infrequent UPS user on a stable grid. Even when only cycled on a monthly basis, a lithium-ion UPS can theoretically maintain run-time for 41 years. The UPS is far more likely to be replaced due to obsolescence of the network card than the battery losing functionality. For a frequent user of back-up power, the benefits of high cycle life and capacity retention are still strong, though on an abbreviated scale.

OPERATING TEMPERATURE

An increasingly popular topic of discussion is data center temperature. Current ASHRAE guidelines recommend a maximum operating temperature of 27°C, which is a significant cooling burden on a facility. However, empirical data on server life captured during failures of HVAC systems has led some industry experts to question the validity of this recommendation. A 2008 study by Intel compared servers run in an air-conditioned environment with those in a non-conditioned environment with a maximum temperature of 33.3°C and no humidity or dust filtration.[2] Over ten months, the failure rate of servers in the lesser controlled environment was only 2% higher than that of the air-conditioned environment. However, the reduction in energy consumption was a noteworthy 67%.

Allowing that servers are more robust to higher operating temperature than guidelines suggest, it is necessary to confirm that other data center equipment is similarly inured. When comparing specifications for a lithium-ion and lead acid UPS, only the lithium-ion based systems offer nameplate power and run-time capabilities across the entire standard operating temperature range of 0-40°C. In addition, lithium-ion batteries maintain the same cycle life benefit seen at 23°C, offering 800% more cycles at 40°C than lead-acid.[3] As data center operators begin deploying more granulated thermal management systems, any piece of equipment—especially a UPS—that does not require heavy air conditioning will directly reduce facility energy consumption and overall operating costs. In addition, thermally robust equipment is more solidly inured to rising temperatures during a prolonged power loss event.

DATA COLLECTION

A burgeoning trend—both in the data center and the world at large—is the deployment of connected devices reporting noteworthy data to the user. In the context of a UPS, the critical data will concern notification of a power outage, health of the battery, and faults. Traditionally, intelligence around the state of the battery actually originates from the power electronics. State-of-charge is based on an estimation of charge-current over time and measured voltage. Capacity is calculated by completing a full discharge cycle and comparing actual capacity with expected capacity. While this approach has been satisfactory in the past, more users are focusing on granularity and quality of data to allow tighter operating margins.

An increasingly common way to address this need is the use of a battery management system (BMS). The BMS is hooked up directly to the battery cells, allowing direct monitoring of current, voltage and even temperature. This cell-level approach—as opposed to pack-level—gives the user greater insight into the health and reliability of the UPS battery, as well as more effective fault/error analysis.

It is worth noting that lithium-ion batteries like the Methode AC6000 typically have a BMS integrated directly into the pack. The BMS performs the dual purpose of both providing critical data to the user and ensuring the battery remains in a safe operating conditions. Many off-the-shelf solutions exist for lead-acid batteries, as well, but require user installation and come at significant cost (the APC solution compatible with the unit tested in this study is almost twice the cost of the UPS itself.)

SUMMARY

As reliability of American power grid decreases due to volatile weather events and aging infrastructure, the need for a strong back-up power approach increases. The use of lithium-ion batteries in lieu of lead-acid in data center UPS solutions offer benefits that meet the challenges of the day. High cycle life, capacity retention and thermal robustness make the lithium-ion-based UPS a straight-forward replacement for the maintenance-heavy lead-acid solutions commonly used today.

References

[1]Eaton, "Power Outage Annual Report: Blackout Tracker." February 2015.

[2]Kassner. "Why Aren't Data Centers Hotter?" Data Center Dynamics. 2015. 13 October 2015.

[3]Albright, Edie, and Al-Hallaj. "A Comparison of Lead Acid to Lithium-ion in Stationary Storage Applications." AllCell Technologies. 2012. 12 December 2013.

About Methode — Active Energy Solutions

Active Energy Solutions (AES), a Methode Company, is a leader in lithium-ion battery systems and power electronics. Since its inception in 2006, AES has designed, tested and produced a variety of customized energy storage systems to deliver greater efficiency in battery energy density, life and footprint for our data storage, telecom and alternative energy customers. Designed to integrate flawlessly with Methode's DCIM and PDU solutions, we help clients better manage their power resources with intelligent products and services, delivering more data center real estate while reducing operational expense from day one.

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