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Thought Leadership White Paper

Emerging UPS Standby Power Sources

Four Promising Alternatives to the Lead Acid Battery

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Executive Summary

Though an uninterruptible power supply (UPS) performs many important functions, most users value them chiefly for the emergency energy they provide during a power outage. UPSs give IT personnel the time they need to protect sensitive equipment and data from the effects of an electrical service interruption by shutting down systems in an orderly fashion or starting a backup generator.

Today, most UPS products use lead acid batteries to store emergency standby power. A proven technology with many decades of successful service in a variety of industrial settings, the lead acid battery remains the most cost-effective energy storage solution as measured by dollars per minute of backup time.

Yet despite these merits, lead acid batteries are unpopular among data center managers due to their size, weight, maintenance requirements, toxic contents and relatively short lifespan, among other issues. As a result, UPS makers have long been searching for an alternative standby power technology that's smaller, simpler and "greener" than lead acid batteries, yet no more expensive to operate.

Today, that hunt just may be nearing its end. Several exciting new standby power solutions, all rapidly approaching mainstream commercial viability, appear poised to give the lead acid battery a run for its money. This white paper will explore the strengths, weaknesses and future prospects of four such technologies: Flywheels, ultracapacitors, fuel cells and lithium ion batteries.

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The Pros and Cons of the Lead Acid Battery

Lead acid batteries are hardly a cutting-edge technology. In fact, the first one was invented some 150 years ago. Yet they remain the standby energy storage solution of choice in UPS products today, and with good reason: No other mainstream technology handles the unique demands of the data center as effectively or affordably.

Unlike the batteries in a forklift or hybrid gas-electric car, which get regular and steady use, the batteries in a UPS spend most of their time idle. Then, perhaps two or three times a year, a power outage occurs, causing the UPS to discharge its batteries very rapidly and at high current. When power is restored, the UPS recharges the batteries, which then enter another extended waiting period.

Thus, while UPS batteries aren't used often, when they are used it's usually fast and hard. Lead acid batteries are an almost ideal fit for such an environment, as their internal chemistry enables them to provide high amounts of current on short notice, yet still provide a reasonable service life in float or idle mode. Moreover, lead acid batteries deliver relatively high amounts of backup time—typically five to 15 minutes—at a relatively low price, making them the most cost-effective standby power storage solution currently available.

However, lead acid batteries also come with a significant set of offsetting disadvantages:

- **Cumbersome size and weight:** Lead acid batteries are bulky and extremely heavy. Indeed, the batteries in a typical medium-sized UPS weigh five to eight tons. As a result, lead acid batteries offer lower energy-to-weight and energy-to-volume ratios than some other battery designs.
- **High maintenance costs:** The sealed lead acid batteries typically used in today's UPS products are often referred to as "maintenance free." In fact, however, they should be inspected at least twice a year to ensure that they're tightly connected, free of corrosion and in good working order. Hiring specialists to perform such work might cost $1,000 per year or more.
- **High replacement costs:** Sealed lead acid batteries generally have a four to five year service life. That means data centers must budget to replace them two to three times over the lifespan of a typical UPS.
- **High disposal costs:** The batteries in an average UPS contain up to several hundred gallons of highly toxic sulfuric acid. As a result, disposing of them is an expensive and tightly-regulated process. Most UPS owners ship their used batteries back to the manufacturer for recycling, which entails covering freight costs for several tons of extremely hazardous cargo. Disposal costs should always be included in the battery replacement cost estimates and specifically reference proper disposal process based on the country requirements for battery disposal and recycling.
- **Unpredictable reliability:** The only sure way to confirm that a lead acid battery is ready to provide emergency backup power is to conduct a test discharge. Unfortunately, however, every time you test a lead acid battery you permanently reduce its capacity and shorten its operating life. Though the battery testing programs built into most modern UPSs reduce such battery wear, they do not eliminate it.
- **Battery monitoring systems:** Several commercial systems are available to constantly measure individual battery performance and provide real-time reports and alarms when batteries may need attention or replacement. These are fairly sophisticated tools, can be costly and require a user to interpret the information and follow through on arranging a qualified vendor to inspect or replace the identified battery. Used correctly, battery monitoring systems can extend the useful life of sealed lead acid batteries and prevent disruptions when an individual battery fails resulting in shorter backup times.

Alternative Standby Technologies

Given the lead acid battery's many flaws, it's no surprise that data center managers have long been clamoring for alternatives. At present, four such technologies show particular promise. Though none is in

widespread use today and few existing UPS models are equipped to support them, all are likely to gain increased traction over the years ahead.

Flywheels

A flywheel is a mechanical device typically built around a large metal disk. During normal operation, electrical power spins the disk rapidly. When a power outage occurs, the disk continues to spin on its own, generating DC power that a UPS can use as an emergency energy source. As the UPS consumes that power, the disk gradually loses momentum, producing less and less energy until eventually it stops moving altogether.

Advantages:

- **Compact form factor:** Flywheels are significantly smaller and lighter than lead acid UPS batteries.
- **Low environmental impact:** Unlike lead acid batteries, flywheels don't contain dangerous and ecologically-harmful chemicals.
- **Long lifespan:** Flywheels typically enjoy a ten-year service life, versus about five years for lead acid batteries. Moreover, while a battery gets a little bit weaker every time you discharge it, you can use a flywheel hundreds or even thousands of times without impacting its performance or service life.
- **Lower maintenance overhead:** Flywheels are reasonably simple mechanisms that require less—and less expensive—preventive maintenance than UPS batteries.

Disadvantages:

- **Limited backup time:** A typical lead acid UPS battery provides up to 15 minutes of emergency power. A typical flywheel delivers only 30 seconds of standby energy. Companies have the option of installing multiple flywheels, but that still limits them to a few minutes of backup energy.
- **Higher cost:** The metal disk at the heart of most large flywheels usually rests on a bearing that is very expensive and must be replaced approximately every five years. Smaller models utilize magnetic levitation technology rather than a bearing, but are still costly. In fact, the purchase price of the average flywheel-based standby system is roughly double the upfront price of the average lead acid battery-based system. The flywheel's lower maintenance costs and greater durability reduce that gap over time, but do not erase it.
- **Special major maintenance:** Flywheels may contain bearings, vacuum pumps or special assemblies that require a duty cycle replacement based on the manufacturer's recommended interval. Those recommendations vary, so annual service costs will vary over the life of the product. If you perform a Total Cost of Ownership estimate, use a 10-year term to fully capture these special recurring costs.

What the future holds: Though flywheel technology is improving, progress has been slow. As a result, flywheels capable of generating power for significantly longer than 30 seconds are unlikely to be available any time soon. For most organizations, 30 seconds isn't enough time to prepare critical IT systems for the impact of a major power outage, so broad adoption of flywheels as an exclusive source of standby data center power will probably be limited over the near term.

However, usage of flywheels is likely to expand in specific scenarios for which they are well suited. For example, most hospitals have generators that can be ready for use within ten seconds of a power failure. In such settings, 30 seconds of standby power is perfectly adequate, making flywheels an attractive alternative to the lead acid battery.

In addition, companies may eventually use flywheels to supplement batteries rather than replace them. Over 95 percent of power outages last just a few seconds, and longer, more serious, failures generally occur just a few times a year. Hybrid solutions, in which a flywheel provides standby power during brief outages and batteries handle lengthier incidents, can extend the batteries' service life, producing significant savings.

Ultracapacitors

Also known as supercapacitors, ultracapacitors are specialized, extremely high-density batteries. They typically contain non-toxic, carbon-based materials such as activated carbon and graphene.

Advantages: Ultracapacitors share many of the advantages of flywheels. They are smaller and lighter than lead acid batteries, and contain no sulfuric acid. You can also discharge and recharge them as often as you want without impacting their capacity, performance or lifespan. What's more, an ultracapacitor is a solid-state device with no moving parts, so there's less need for maintenance.

Disadvantages: Like flywheels, ultracapacitors provide power in extremely short bursts. In fact, a typical ultracapacitor delivers just ten seconds of standby energy.

Ultracapacitors are also costlier than lead acid batteries. On average, the upfront cost of an ultracapacitor is roughly one and half times that of a lead acid battery.

What the future holds: Within the next three to five years, technological advances are expected to lengthen the average backup time provided by an ultracapacitor from ten seconds to as many as 30. However, that's still too little standby power for most data centers, suggesting that ultracapacitors are unlikely to become a widespread alternative to the lead acid battery in the near future.

On the other hand, once their capacity reaches 30 seconds, ultracapacitors may emerge as a popular alternative to the flywheel, as they are somewhat cheaper and just as effective in settings that require only short spurts of backup power and in hybrid standby solutions that draw on lead acid batteries during lengthy outages.

Fuel Cells

Unlike batteries, fuel cells generate power rather than store it. A fuel cell is basically an electrochemical device that converts fuel (typically hydrogen) into energy. However, unlike an internal combustion engine, which also converts fuel into energy, a hydrogen-powered fuel cell's only exhaust product is water. As a result, everyone from auto makers to electrical utilities to UPS manufacturers is presently either introducing fuel cells to their product lines or investigating their use.

Advantages:

- **Environmentally friendly:** Unlike lead acid batteries, fuel cells pose little danger to the environment.
- **Long backup times:** A fuel cell will supply emergency power continuously for as long as you supply it with hydrogen fuel. That means the average fuel cell provides far more standby energy than a lead acid battery or any of the three other alternative standby power sources discussed in this white paper.

Disadvantages:

- **Safety concerns:** Hydrogen is flammable, so fuel cell users must take extreme care in how they install, store and support them.
- **High cost:** Though prices have come down significantly in recent years, fuel cells are still far more expensive than lead acid batteries.
- **Delayed start time:** It typically takes about 30 seconds to get a fuel cell up and running at full power. As a result, fuel cell-based UPSs usually employ a small battery to provide backup power during that startup period.

What the future holds: Fuel cell manufacturers are experimenting with less flammable alternatives to hydrogen, which could improve safety and accelerate adoption rates. However, while fuel cell costs are declining, they are still considerably higher than those of lead acid batteries and likely to remain so for some time. As a result, fuel cells will probably see only limited deployment as a UPS standby power source over the next few years.

Lithium Ion Batteries

Most cell phones and laptops use lithium ion batteries, which have grown steadily smaller, lighter and denser over the last decade. Though they're rarely used today in industrial settings or data centers, lithium ion batteries are capable of performing most of the same functions as lead acid batteries.

Advantages and disadvantages: The best lithium ion batteries currently available deliver a 30 percent weight saving and 30 percent footprint saving over lead acid batteries, while improving backup time by 30 percent. Unfortunately, they also cost four times as much as comparable lead acid models. And safety is a concern too: Lithium ion batteries may explode if overheated or overcharged, and they burn profusely when ignited.

What the future holds: Today's lithium ion batteries are too expensive to serve as an effective alternative to lead acid UPS batteries. However, the lithium ion cell's small size and high density make it an attractive option for use in hybrid and plug-in electric vehicles. As a result, car manufacturers are working actively with suppliers to develop safer, more compact and more affordable models. In fact, experts now predict that lithium ion batteries will offer roughly the same total cost of ownership as lead acid batteries within about two years. At that point, many observers believe, lithium ion batteries are likely to become the preferred technology for UPS standby power.

Conclusion

The long quest for a viable alternative to the lead acid battery is closer to conclusion than ever before. Flywheels, ultracapacitors, fuel cells and lithium ion batteries all offer important advantages over lead acid batteries as a UPS standby power solution. However, they also have serious drawbacks at present. In particular, they are all far more expensive technologies than lead acid batteries—and cost reigns supreme as the top consideration for most UPS buyers.

Still, this picture is changing rapidly. Already, flywheels and ultracapacitors are practical, cost-effective options in a limited set of scenarios. And with demand growing for more efficient, environmentally-responsible energy storage solutions, manufacturers are working diligently to shrink the cost and address the shortcomings of the alternative standby technologies discussed in this white paper.

As a result, if one thing is certain in the standby power arena, it's that tomorrow's technologies will look different, operate more reliably and offer lower cost of ownership than today's systems. And "tomorrow" may be right around the corner.

About Eaton

Eaton Corporation is a diversified power management company with 2008 sales of $15 billion, with approximately 75,000 employees and customers in more than 150 countries.

Eaton is a global technology leader in electrical systems for power quality, distribution and control; hydraulics components, systems and services for industrial and mobile equipment; aerospace fuel, hydraulics and pneumatic systems for commercial and military use; and truck and automotive drivetrain and powertrain systems for performance, fuel economy and safety.

Eaton manufactures sells and supports UPSs that meet the demands of today's data center equipment. All Eaton UPSs for data centers meet or exceed the specifications of IT power supply units for reliable, high quality power. For more than 40 years—from the first commercial UPS to the modular Eaton BladeUPS for high-density server environments and ultra-high-efficiency UPSs—Eaton has set the standard for power protection and backup power.

In addition to UPSs, Eaton is your source for a comprehensive range of data center solutions, including power distribution, power protection, rack enclosures and accessories for network closets, computer rooms and data centers.

To find out more, visit www.eaton.com or call us at 800-356-5794.

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