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 starting a backup generator, shutting down systems in an orderly fashion, or moving data and processing to a disaster recovery site.

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 is usually the most cost-effective energy storage solution as measured by dollars per minute of backup time.

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

Today, that hunt is 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: Lithium-ion batteries, flywheels, ultracapacitors and fuel cells.

Figure 1: Lead acid battery

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Traditional choice: Lead acid

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.

Advantages:

- **Internal chemistry:** Lead acid batteries are an almost ideal fit for the unpredictable and inconsistent IT 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.
- **Backup time:** Lead acid batteries deliver relatively high amounts of backup time—typically five to 15 minutes.
- **Price:** Lead acid batteries are available at a relatively low price, making them the most cost-effective standby power storage solution currently available but now that is changing rapidly, as other technologies have 'caught up' in affordability. Competitively priced alternatives exist today.
- **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. Newer ones can proactively detect and mitigate thermal runaway, a dangerous condition. These are fairly sophisticated tools, and 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.

Disadvantages:

- **Form factor:** 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 types.
- **Costs:** Between maintenance, replacement and disposal, lead acid batteries have a much higher lifecycle costs associated with them.
  - **Maintenance**: 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 $2,000 per year or more, depending on the battery size.
  - **Replacement:** Sealed lead acid batteries generally have a five to six year service life. That means data centers must budget to replace them two to three times over the lifespan of a typical UPS.
  - **Disposal:** The batteries in an average UPS could contain up to several hundred gallons of highly toxic dilute sulfuric acid. As a result, disposing of them is legally required, expensive and a 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.
- **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-discharge a lead acid battery you permanently reduce its capacity and slightly shorten its operating life. Though the battery testing programs built into most modern UPSs reduce such battery wear, they do not eliminate it.

Alternative #1: Lithium-ion

Most cell phones and laptops use lithium-ion batteries, which have grown steadily smaller, lighter and denser over the last decade. In industrial settings or data centers, lithium-ion batteries are capable of performing the same functions as lead acid batteries, while offering significant additional benefits.

Figure 2: Lithium-ion

Advantages:

- **Compact form factor:** The best lithium-ion batteries currently available deliver a 60 percent weight saving and 40 percent footprint saving over lead acid batteries
- **Improved backup time:** The batteries are not only much lighter and smaller, but also improve backup time by 30 percent.
- **Long lifespan:** Lithium-ion batteries feature a 10-year service life and a much higher cycle life, which will save you money in the longrun. This makes them ideal for grid-sharing applications, being considered by some data center operators.
- **Battery monitoring system:** Leading lithium-ion batteries have a built-in battery management system to provide automatic balancing, optimization, and protection for temperature, voltage levels and current concerns.

Disadvantages:

- **Higher cost:** Until recently, lithium-ion batteries cost several times as much as comparable lead acid models upfront.
- **Safety concerns:** Safety is a concern. If overheated or overcharged, lihtium-ion batteries have been known to explode and burn profusely when ignited. However, lithium chemistries for UPS applications use safer chemistries, and active management systems that disconnect a failing battery long before a dangerous condition develops.

What the future holds:

Today's lithium-ion batteries are now able to serve as an attractive alternative to lead acid UPS batteries. The lithium-ion cell's small size and high density make it the best 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 agree that lithium-ion batteries now offer a lower total cost of ownership than lead acid batteries. Many observers believe lithium-ion batteries are likely to become the preferred technology for UPS standby power.

It is worth noting that lithium-ion is not the only new battery chemistry that holds promise for UPS applications. Nickel zinc, Sodium sulfur, and even saltwater batteries are currently being tested with UPS systems. These chemistries offer excellent performance and an even better safety profile than either lead acid or lithium-ion.

Alternative #2: 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.

Figure 3: Flywheel

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 most 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 and lower total cost of ownership:** Flywheels are mechanical, rather than chemical storage systems that require less—and less expensive—preventive maintenance than UPS batteries.

Disadvantages:

- **Limited backup time:** A typical lead acid UPS battery provides 3 to 15 minutes of emergency power. A typical flywheel delivers only 15 to 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. Models with high speed lighter weight disks utilize magnetic levitation technology rather than a bearing, but are still costly to buy. In fact, the purchase price of the average flywheel-based standby system may be 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 15-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, practical 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 often use flywheels to supplement batteries rather than replace them. Over 95 percent of power outages last just a few seconds, and the 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, possibly reducing the number of battery replacements over the UPS life.

Alternative #3: Ultracapacitors

Also known as supercapacitors, ultracapacitors are specialized, extremely high-density, high speed energy storage options. They are a non-mechanical alternative that typically contain non-toxic, carbon-based materials such as activated carbon and graphene. They are a non-mechanical alternative.

Figure 4: Ultracapacitor

Advantages:

- **Compact form factor:** Like the flywheel, ultracapacitors are smaller and lighter than lead acid batteries.
- **Low environmental impact:** Ultracapacitors (as well as flywheels) contain no sulfuric acid, which alleviates concerns regarding disposing toxic chemicals.
- **Charge does not affect lifespan:** You can also discharge and recharge them as often as you want without impacting their capacity, performance or lifespan.
- **No maintenance:** An ultracapacitor is a solid-state device with no moving parts, so there's less need for maintenance.

Disadvantages:

- **Limited backup time:** Like flywheels, ultracapacitors provide power in extremely short bursts. Until recently ultracapacitor delivered just ten seconds of standby energy. Modern UltraCap systems now can deliver up to 30 seconds of backup time, making them a non-mechanical alternative to flywheels.
- **Higher cost:** Ultracapacitors are also costlier than lead acid batteries. On average, the upfront cost of an ultracapacitor is roughly twice that of a lead acid battery.

What the future holds:

Within the next three to five years, prices will continue to fall, and demand will increase as users become comfortable with ever shorter backup times.

Alternative #4: 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 or natural gas) 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 testing fuel cells in their applications, or investigating their use. A few, more progressive data center clients use fuel cells in tandem with utility power in a 2N, or dual bus configuration.

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 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.

Disdvantages

- **Higher cost:** Though prices have come down significantly in recent years, fuel cells are still far more expensive than lead acid batteries. Power cost is a consideration, as typical fuel cells are only about 85 percent efficient.
- **Safety concerns:** The fuel source is flammable, so fuel cell users must take extreme care in how they install, store and support them.
- **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 but may see increased deployment in distributed energy environments, where they become the primary power source.

Conclusion

The long quest for a viable alternative to the lead acid battery is closer to conclusion than ever before lithium-ion batteries, flywheels, ultracapacitors and fuel cells all offer important advantages over lead acid batteries as a UPS standby power solution. However, some of these still retain a higher cost vs. lead acid technology—and cost reigns supreme as the top consideration for most UPS buyers.

Still, this picture is changing rapidly. Already, lithium-ion and flywheels 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 new technologies will look different, operate more reliably and offer lower cost of ownership than today's systems. And the next breakthrough in storage technology may be right around the corner.

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