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NiMH Batteries Projected to Replace Flywheels For Critical Bridge Time Applications

Dennis DeCoster, Principal
Mission Critical West, Inc.

The Age of the Bridge

Bridge time (5 to 15 seconds DC reserve) uninterruptible power supply (UPS) applications hit their first major stride during the Dot Com explosion (~2000). Although such systems had been available and installed for almost 30 years on industrial applications, this marked the first time any significant penetration had been made into mission-critical applications such as data centers and co-locations (CoLo's).

The drive for this was simple. At the time, conventional UPS, along with their preferred flooded lead acid (FLA) batteries were completely sold out and had delivery times approaching one full year. Remembering the "first to market at any cost" psychology of the time, bridge time (flywheel then) products gave an immediate and desirable solution. 15 seconds was more than enough time to bring backup diesel genset systems, which all critical sites had, on line. CoLo's, Internet development operations and even some conventional data centers ordered fast and furious. European CPS (continuous power system) manufacturers were the prime beneficiaries. Today, there are some one billion dollars worth of "15 second" UPS and CPS systems running worldwide, unbeknownst to most people, even in the power quality industry.

While there is still some resistance to a 15 second DC storage approach versus the old 15 minute convention, knowledgeable people realize that true Tier 3 or 4 sites can never go down and therefore are invariably equipped with the highest reliability diesel electric generation systems available. These are typically N+1 or N+2 redundant and, due to a strong preventive maintenance program, invariably start within 10 seconds. I give seminars to a lot of diverse groups and routinely ask the audience if their gensets have ever failed. A "yes" response (truly very rare for high criticality sites), is always for the same reasons: poor maintenance, lack of testing or both.

The most common failure items are the lead acid start batteries. In a true 7 by 24 operation, people get fired if this is allowed and so it does not generally exist. Nor do the blown pistons, injectors, belts or other items common in prime genset use (construction sites, strip malls, rentals, etc), but NOT in 200 hour a year standby service.

Ironically, the group I was getting the most stares and disagreements from was the diesel generator service technicians themselves. In their sphere of influence, they were right. Diesels do not necessarily start first time, every time. But that was because they spent 90 percent of their time repairing non-critical prime and rental service systems that usually only got attention when they finally broke down.

So the paradigm changes. No longer is "soft shutdown" allowed and so, 15 minutes or 15 seconds of DC storage is completely irrelevant. Only continuous uptime is tolerable. Enter extreme reliability bridge time solutions.

Bridge time products include low and high speed flywheels, ultracaps and some non lead-acid batteries. Having had experience with all of these, and having struggled through several unscheduled bearing failures for two of the three largest flywheel manufacturers, I have come to the conclusion that two technologies, at this point in time, have the most to offer. One is high speed flywheels, meaning magnetic bearing flywheels because they have no bearing changeouts, the other is nickel metal hydride (NiMH) batteries. MC West has published papers that describes each of these, but suffice it to say that NiMH batteries wins hands down even between these two. The reasons are clear: no moving parts, no maintenance, superb reliability and installed cost half of most flywheels.

Lead Acid Batteries - A Primer

Flooded Lead Acid (FLA) Batteries

Flooded lead acid batteries, also known as vented or wet cell batteries, have been the preferred choice for high criticality data center UPS system designers as well as other 7 by 24 UPS applications for decades. FLA battery jars are very large and heavy, typically weighing perhaps 500 lbs. each. These battery systems are normally very reliable and typically last most, but not all, of their 20 year (pro rata) warranty period. The normal failure mode is shorted rather than open cell, in contrast to their sealed lead acid (SLA) counterparts. This is significant because a 15 minute single string FLA system will typically loose just 30 seconds to a minute with a short circuit failure (caused, lets say, by sediment buildup).

The result on uptime/availability is not in any way critical taking a 15 minute battery system to perhaps 14 minutes. But there are also ways to experience open circuit failure in FLA cells. Post seal leaks, case cracks caused by plasticizer loss with aging and aggravated by seismic events, incorrect installation grease case damage, extreme plate growth and other events can cause loss of electrolyte. When this occurs, the result is immediate and catastrophic because FLA batteries are almost always designed in single string configuration. So all UPS back-up is lost. Regular maintenance is an absolute must for these systems.

Separate, very large battery rooms must be built with a wide array of support equipment for lead acid batteries (See Figure 1). This routinely includes spill containment and neutralization, air exchange systems (for hydrogen build-up), cooling systems, eye washes and showers, hydrogen detection systems, perhaps fire suppression and monitoring systems as well. The installed cost of such systems is many times the cost of sealed lead acid (SLA) batteries. But then again, so to is expected reliability.

Sealed Lead Acid (SLA) Batteries

Figure 1. Typical large flooded lead acid battery system

Sealed lead acid batteries, sometimes called recombinant, absorbent glass mat (AGM) or (incorrectly) "maintenance free", are available from dozens of manufacturers. For UPS application, most common by far are gelled electrolyte and valve regulated lead acid (VRLA) types with design life of five years. These batteries may be warranted for five or 10 years but regardless of warranty, typical useful life routinely falls between three and five years. Much more expensive (three to four times) 20 year pro rata sealed products are also available with higher lead content and useful lives about twice the common SLA type.

SLA batteries are the product of choice for small UPS, low bid and/or non-critical applications. Since they are inexpensive, these batteries are outselling their more reliable FLA counterparts by three or four to one worldwide. They are typically half the size and weight of FLA, and usually (but not always) escape local code requirements for spill containment or air changes.

By definition, these products are sealed, allowing no possibility of water add. During charge and discharge electrolysis, hydrogen is generated, which is trapped and recombined with generated oxygen to form water. But some generated gases are lost to overpressure release through integral valves, thus leading to a major and unsettling failure mode of SLA batteries - dryout.

Dryout is an open circuit condition causing loss of the entire string for any single cell loss. Almost as problematic as dryout failure itself, is the fact that is impossible to predict exactly when a cell will fail. Because of this, great care must be taken in design and use of SLA batteries for medium to high criticality applications.

Sealed lead acid batteries make up almost 90 percent of all DC storage for UPS systems. First and foremost, never use single string designs. Always have at least one redundant string for all expected load conditions. Next, never let these batteries push the far end of their service life. End of life for SLA batteries follows a traditional bath tub curve. After minimal failure in one to three years, failures rise nearly exponentially in years four and five. During this period, some published reports show string Meantime Between Failures (MTBF) on a VRLA-backed UPS system as low as 2,000 hrs or less. Although nearly as expensive as adding another string, it may be worth considering battery monitoring, which trends impedance or conductance as well as voltage to get at least some hope of failure prediction. Full load discharge testing can also be problematic as the batteries age. When you need such testing most, near end of life, it can actually put a system more at risk since there are only so many such discharges available before failure.

Why NiMH? Reliability

With NiMH, there is virtually zero chance of open circuit failure from dryout, the single biggest threat to high availability. Why? In a typical 200 cell sealed battery system, just one battery failing open circuit means the entire string is lost. So 15 minutes does not become 14 minutes, it becomes zero minutes. Sealed lead acid batteries also have issues with thermal runaway, sharp reliability drop-off after three to four years, weak predictability and other problems that NiMH does away with. And unlike flywheels that also are designed for 15 seconds, there are no moving parts, no complex controls, no high parts count, no high speed danger or bearing change-outs.

Advantage Nickel Metal Hydride (NiMH)

Below (See Figure 2) is a picture of a Cobasys NiMH battery system designed for minimum 15 seconds DC energy storage for a 750 kVA, 675 kW UPS module. This module occupies less than 9 sq. ft. of floor space and can be stacked side to side. By comparison, sealed lead acid batteries require at least four times this floor space, and flooded lead acid batteries need ten to twenty times this space. Similarly, weight is reduced four to 10-fold.

Figure 2. 750 kVA UPS battery , <9 sq. ft.

NiMH batteries also cycle almost indefinitely, handle temperature far better than lead acid, and do not need much (if any) maintenance since there are no soft lead retorque issues, watering needs or other maintenance headaches.

Scalability, the Ultimate Advantage

NiMH Bridge battery modules are perhaps most different from flywheels in one respect. They are scalable. (See Figure 3) Using the 750 kVA UPS example, the Cobasys NiGuard Bridge is outfitted with nine strings to provide the required capacity. So one more string means N+1 redundancy. Two more strings (economically very feasibly) means N+2 redundancy. You could even have N+8 redundancy without moving past a single expansion rack or cabinet. OK, redundancy and reliability are assured. What about capacity? Unique to the NiMH solution, if it turns out that, say, 40 seconds, rather than 15 seconds of DC reserve are required, due to diesel paralleling time constraints or other issues, this is not a problem, nor is five minutes, or even 15 minutes for that matter. Since we are talking simple batteries here, expansion is easy if and when desired.

Figure 3. Scalable, redundant 20 to 60 second 750-1,500 kVA NiMH Bridge

Green Concerns

NiMH batteries have no lead, no acid, no high spinning flywheels and no recycle issues whatsoever. The chemistry is nickel, potassium and inert rare earths. There is no possibility of appreciable hydrogen generation during any normal operating mode. So no eye washes, showers, hydrogen monitoring, spill containment, explosion barriers (flywheels), EPA recycle programs or any other issues to deal with.

Cycling and Temperature

Lead acid batteries invariably have cycle limitations. This means that warranties are tied to the number of times the UPS batteries see discharge and recharge events. Those numbers are rather small, amounting to just 100 (or less) full load discharge cycles over the entire life of the battery for some of the most popular and most reliable UPS batteries. NiMH batteries are far different. Figure 4 shows NiMH batteries tolerating over ten times the number of full load discharges, and 100 to 1,000 times that number for partial discharges typical of those seen on 15 minute batteries on diesel genset equipped sites.

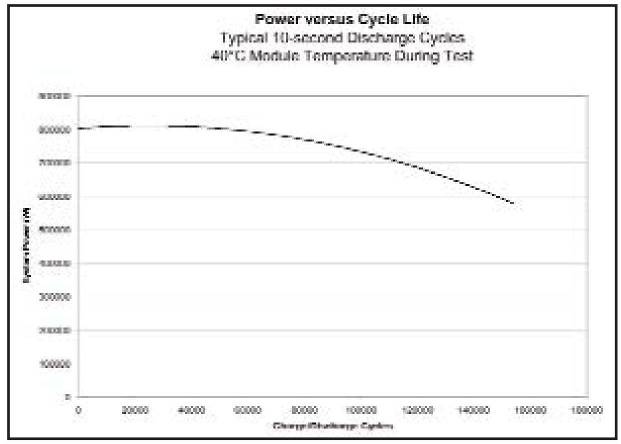

Figure 4.

High temperature is an absolute killer for UPS batteries. At 104°F (the temp most UPS systems are rated for), a five year design life (10 year pro rata warranty) sealed lead acid UPS battery drops to just over one year of projected service life. NiMH batteries easily tolerate 104° temperatures, allowing four or five times the expected service life over lead acid.

Conclusion

NiMH batteries have all the positives of Bridge DC reserve flywheel solutions. They are exceptionally reliable and predictable, compact, low maintenance and easily monitored. But unlike flywheels, they are far simpler, require no bearing changes, are highly scalable, are safer and have no moving parts save the exhaust fans. Best of all, the installed cost is much lower than flywheels, ultracaps, or any other DC Bridge storage technology available today.

Dennis DeCoster is Managing Principal/Principal Site Engineer of Mission Critical West, Inc. He is an acknowledged expert in DC storage systems with more than 15 years field experience in low and high speed flywheels and lead and nickel battery systems.

Contact Dennis DeCoster at dd@mcwestinc.com or at www.mcwestinc.com.

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7355 E. Orchard Rd., Ste. 100, Greenwood Village, CO 80111 USA Phone 720-528-3770. Fax 720-528-3771. wwwinfowebcom.com