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New UPS battery technology combines 'wet cell' high reliability with 'sealed battery' ease of installation

By

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Abstract

MC West and its principals have studied, specified and installed a wide variety of UPS batteries as well as both low speed and high speed flywheels over the past two decades. To date, if a client wanted Tier 4 Data Center reliability, you specified flooded lead acid batteries. But flooded or vented batteries are large, heavy, dangerous, maintenance intensive, and require large & complicated support systems. A new Nickel Metal Hydride battery we've recently worked with has 20 year life expectancy similar to flooded cell technology and very high reliability, yet is more compact and green (no Hazmat issues) than VRLA UPS batteries. Among other features, these cells can cycle almost indefinitely, handle heat well, need virtually no maintenance, and require none of the air change & spill control support of lead batteries. Test and early site performance data will be presented along with a comparison against conventional UPS batteries as well as flywheels.

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UPS Batteries Today

When root cause analysis is performed, battery failures account for more Uninterruptible Power Supply (UPS) system failures than all other non-personnel related causes combined. Much of this is due to incomplete, overdue or improper maintenance, though the central issue may be the type of technology employed in the most common batteries used for UPS systems.

Lead Acid batteries are far and away the predominant DC power source for modern UPS systems of all sizes and vendors. They outsell flywheels, UltraCaps, as well every other battery technology, combined by almost 10 to 1. Lead Acid batteries can generally be split into two sub-groups, flooded (FLA) or sealed with Valve Regulated Lead Acid (VRLA) being the most popular type in that group.

FLA batteries flood their thick lead-based plates with an acid electrolyte and result in a highly reliable product. Failures normally don't occur until mid way through their 20 year prorata life, and even then, the failure mode is short circuit in the great majority of cases. This is good because any one shorted cell only affects overall reserve time by a very small percentage. Unfortunately, with the good comes the bad. FLA batteries use concentrated sulfuric acid and require spill containment, eye washes, safety showers, explosive hydrogen monitoring and air change-outs, and frequent maintenance to replace water and re-torque soft lead connections. This makes for very expensive, heavy and highly space consuming separate battery room requirements to use this technology.

Fig 1. A very unique project, this client required massive <u>above</u> slab reinforcement to accommodate the weight of a flooded battery addition to its existing UPS battery room.

VRLA batteries do away with the size & expense of separate battery rooms. Intrinsic to their design, these sealed cells normally generate little hydrogen, entrain their concentrated acid in glass mats, and are much smaller than FLA batteries. But VRLA batteries also do away with the *reliability* of their FLA counterparts. VRLA batteries are far less expensive and outsell FLA types by an order of magnitude, but they are also an order of magnitude less reliable and less predictable. The fact that these cells are sealed means that no water can be added to replace that which is lost through the regulating valves during discharge and recharge in the form of hydrogen and oxygen. The end result more often than not is *open* circuit failure from dry-out. A single battery failing open circuit unpredictably can and will take an entire 50 to 100 battery string off line and inoperable. For most commonly purchased UPS batteries, this can generally take place in as little as four or five (4-5) years. VRLA batteries also have the potential for an insidious and often explosively catastrophic failure mode known as thermal runaway. In that extreme condition, cell resistance builds, requiring ever increasing charge current, which in turn continues to increase resistance until catastrophic failure occurs. Fortunately, this condition is relatively uncommon for most well maintained sites, but can and does occur.

Fig. 2a 3-5 yr VRLA batteries in cabinets

Fig. 2b Failed VRLA battery

VRLA batteries commercially are marketed in 5, 10 and 20 year theoretical designs and prorata warranties. Few if any ever approach their design life in real world application. And even the best cannot handle heat. A recent Battcon paper on VRLA reliability[1] made the statement (referencing high quality US made 20 year 2V cell AGM-VRLA product) that "even if the standard cells could avoid negative discharge, they would still fail by *dryout* in about 5 years at 90^{o} F (32^{o} C)". Again, this is for a "20 year" premium VRLA product.

DC Alternatives

As many readers will note, MC West has reviewed and evaluated a wide variety of alternate DC power sources for UPS back-up. These have included high and low speed flywheels, UltraCaps, Lithium-based batteries, fuel cell-based DC, and others[2]. With every technology it seems, negatives always appear to offset the positives. With low speed flywheels, it is the cost and downtime of bearing replacements; with high speed flywheels, it is the complexity of controls or potential hazard of high RPM; with many Lithium batteries, it is either explosion hazard or short life; with UltraCaps, similar open circuit fail issues as with VRLA; with NiCad, it's Cadmium toxicity and memory effects. So is any technology staged to make a run at Lead Acid for critical UPS applications?

Enter Nickel Metal Hydride

Perhaps one of the most promising and near term of all UPS battery technologies we see today is Nickel Metal Hydride (NiMH). NiMH has been proved for years in rigorous HEV (Hybrid Electric Vehicle) applications as well as more innocuous applications in laptops and cell phones. Sharing some similarities with Nickel Cadmium batteries, long used for highly reliable diesel genset starting and some telecom applications, NiMH has notable differences. NiMH has shown itself to have virtually unlimited cycling capability in typical UPS applications, a far cry from lead acid DC products which literally every vendor limits sharply in their warranty language. This is evidenced by the performance proven by hundreds of thousands of hybrid electric cars charging and discharging each day.

Fig 3. Early S.D. Metro bus with roof mounted NiMH batteries (1997)

NiMH UPS batteries are smaller and lighter than even VRLA batteries, and have no lead, acid, Cadmium, or hydrogen evolution to be concerned with. Therefore, no special separate battery room construction is needed. NiMH also has a higher temperature tolerance than lead acid. This allows the product to be paired with a un-airconditioned (but properly ventilated) UPS module which is routinely rated at 40 degrees C (104 degrees F) if the application demands that.

Fig. 4a NiMH module

Fig 4b NiMH rack

Reliability, the hallmark of a UPS battery

As uptime experts in critical facilities infrastructure, MC West was particularly intrigued by the improved predictability and ultimate failure mode of NiMH. Although sealed somewhat like a VRLA cell, these batteries do not exhibit the type of unpredictability or early open circuit failure rates common with VRLA. This is directly attributable to the nickel – alkaline chemistry involved. We will not get into a chemistry lesson in this paper, but suffice it to say that the combination of rare earth based hydride alloy and nickel/metal compounds allows use of steel casing and greatly limits electrode growth during charge-recharge functions. The result is long, stabile life even at high cycle rates and elevated temperature. Cobasys, the primary producer of NiMH UPS cells in the USA, feels strongly enough about the reliability and predictability of these cells, that they offer a standard ten (10) year full replacement (not "prorata") warranty with the product. We have not seen this done with any lead acid product, even highly regarded flooded lead acid cells.

Fig 5. Four rack NiMH system ½ filled. This footprint can accommodate over 1 MW of UPS for 15 second diesel start bridge time applications

Accelerated life testing is underway at Telecordia, the well-respected organization specializing in such testing and standards writing for the Telecom industry. The results to date seem to have confirmed the projected ten year minimum service life position when used in routine UPS service. The results also indicate excellent service life and performance at accelerated temperature.

We were able to perform a few tests ourselves on a Powerware 9315 UPS mated with a NiGuard NiMH battery system. Reserve time and voltage tail-off varied predictably with temperature and everything worked as it should. We were also able to do some quick cycle tests with a bridge time configuration aimed at 20-30 seconds. Here also things followed a very predictable path with no bad surprises. We managed 6 quick high power rundowns to 30 seconds minimum reserve without overheat within a half hour period.

Fig.6 Author performing cycle testing on Powerware 9315 UPS w/ 15 minute NiMH battery

Service & Monitoring

In Criticality Level C4 through C7 applications[3] (the old "Tier III-IV" in the Uptime Institute convention), service and monitoring go hand-in-hand with system MTBF in achieving high availability. Full preventative maintenance, fast emergency service, and 7 x 24 real time monitoring add greatly to the outcome. For the NiMH product, these items have been taken into account. By design, there is very little to maintain with NiMH. This, again, has been proven out in rigorous HEV service over the last ten years. Reasons include no soft lead terminals requiring re-torque, no acid corrosion, no accelerated plate wear, etc. System checks are actually more important than conventional PM services here. The product we looked at had all required PM's, central station monitoring around the clock, and even four hour response remedial service bundled with the ten (10) year full replacement warranty. This is a great way to eliminate surprises. Most battery industry warranties we are familiar with are "prorata" and have substantial extra charges for replacing batteries or adding monitoring services.

Short duration Bridge Time applications
Perhaps the most interesting application for this new product we see is as a battery/ "flywheel" hybrid. Since the DotCom era, flywheels in critical applications almost instantly went from a concept with little real world credibility, to a having significant piece of the most critical UPS market sector, with installed sales today very rapidly approaching one billion dollars. Designed for 15 seconds diesel start bridge time, flywheels can be more compact and/or lighter than large lead acid batteries, cycle much longer, and usually (but not always) endure higher temperatures for a longer time. Flywheels do in fact work, but have their negative side too. Most problematic, they are many times more expensive than VRLA batteries and as expensive (or more so) than even flooded lead acid batteries. They are also quite complex, may require substantial maintenance, and most importantly, they are not scaleable.

Because NiMH is relatively linear on capacity (reserve time) all the way down to 15 seconds, you can easily design a 15 or 30 second NiMH "flywheel" but with significant advantages over its mechanical counterparts. There are no bearings to replace or fail prematurely. They are far lighter and smaller than even flywheels, with a 250 to 500 kW system occupying just 6 sq.ft. They are scaleable. And… <u>they are batteries</u>. So none of the inverters or transformers or rotors or pumps or complex controls required by virtually all flywheel systems. Put in a 15 or 30 second system today, and should needs dictate (such as may occur when expanding a single diesel to a parallel system), simply add another string for capacity or redundancy. The additional string may even fit in the same 6 sq.ft. rack, if under 2 or 300 kW. Unlike lead acid batteries, you can add that next string 3, 5, even 8 years out without the impedance imbalance concern mandatory with VRLA. If you like, you can even build the system to 15 minutes or more, though we would not typically recommend that with this product. More on these exciting bridge time (or "flywheel" reserve) applications in a future paper.

So let's review. The NiMH battery has exceptional reliability, much more on the order of flooded lead acid batteries than VRLA. There is no acid or lead or appreciable hydrogen generation. It can occupy ¼ to 1/10 the space of flooded batteries and weighs just 10% to 25% of same. It has virtually unlimited cycling capability, much more like flywheels than (lead acid) batteries. It is almost maintenance free, with the primary vendor currently bundling all PM's and even any emergency service in its ten year full replacement warranty (we haven/t seen that on any other UPS battery or flywheel product to date). And it is totally scaleable.

Wow, this much cost a fortune, right? Believe it or not, when we checked pricing, it was close to the lowest price of the cheapest flywheel we could find, almost on the order of a 15 second VRLA battery, if there was such a thing. Needless to say, we were impressed with this product but particularly for 15 to 60 second bridge power ("flywheel") applications.

[1] ***CAN VRLA BATTERIES LAST 20 YEARS?,*** William E.M.Jones, Harold A. Vanasse, Christian E. Sabotta, Joshua E.Clapper, Edward F. Price; **BATTCON 06**, Philadelphia Scientific, 207 Progress Drive, Montgomeryville. Pa 18973, U.S.A.

[2] ***A State of the Art Review of Energy Storage Alternatives for Mission Critical UPS & CPS Power Systems,*** Dennis P. DeCoster, **2005 PQ Conf proceedings**, Mission Critical West Inc., 6010 PCH, Ste 11, Redondo Beach, CA 90277, U.S.A.

[3] ***Criticality Levels™: A New Classification System for Today's Critical Facilities,*** Jerry Burkhardt, Richard W. Dennis, P.E., Phil Curtis, P.E.; **DataCenter Dynamics SF 06**, SYSKA HENNESSY GROUP, Los Angeles/San Francisco/New York, , U.S.A.

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