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Bridge Time UPS Batteries: A Scalable Alternative to Flywheels

by

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Abstract

Flywheels have made major inroads in critical facilities infrastructure power protection since the turn of the century, with sales now approaching some one Billion dollars. Virtually all of these flywheels have been deployed in "15 second" UPS and CPS Bridge Time applications covering the time it takes for the diesel generation system to start and accept load. While generally reliable, flywheels are expensive, not very scalable, and have many complex moving parts to maintain. Now there is a new Bridge Time alternative emerging – Nickel Metal Hydride (NiMH) batteries. Unlike lead acid batteries, these cells do not stop at 2 or 3 minutes minimum reserve, but can go all the way down to 15 seconds. This allows an extremely compact, yet highly reliable and scalable way to transition critical loads, such as data center loads, from a failed utility to backup generators without interruption. We will examine reliability and availability of all three DC storage types. We will also discuss safety issues where NiMH is far safer to work with than either lead acid batteries or flywheels since there are no lead, acid, high speed spinning masses, or excessive hydrogen issues. And we will look at scalability, perhaps one of the most important parameters. If a site later requires 30 or 60 seconds (say for paralleling), or even 15 minutes, additional strings can be added at any time for capacity or redundancy. Both up front costs, as well as recurring (Life Cycle) costs, which are significantly lower than with flywheels will be reviewed.

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What is a "Bridge Time" UPS Battery?

In the old days, a UPS battery was conventionally sized at either 15 minutes reserve if there was no diesel genset backup, or 5 minutes reserve if there was. This was because 15 minutes was assumed sufficient time to allow a soft shutdown of protected computer loads, while 5 minutes was (and is) the approximate minimum time you could get for lead acid batteries. But this paradigm has changed dramatically and permanently. For Tier II and Tier IV sites such as data centers, a "soft shutdown" is intolerable today. All such sites are today equipped with high reliability diesel generation systems, which will start up and support load within a 10 to 30 second timeframe. Therefore, a 15 minute, or even a 5 minute, battery reserve is unnecessary. It may even be a liability if the tradeoff is critical space or reliability when forced to use VRLA batteries to get "high reserve time" at expense of choosing the higher availability/reliability battery type. You can understand this more clearly with a simple analogy. You would never think of using regular dry cell lead or manganese batteries to power your laptop PC. It might be Lithium, except for some of the safety concerns which need more development. No, it will always be Nickel Metal Hydride (NiMH), the safe, reliable, and proven way to protect laptops. Well, the same is now true for UPS system back-up.

Batteries & Batteries

In prior papers and articles, we have explored the various alternatives available for UPS DC reserve power. For most of this paper, we will be comparing the two most popular and promising Bridge technologies – flywheels and NiMH Batteries. But let's quickly review why conventional lead acid batteries do not make good Bridge application choices in the great majority of cases. Studies have proven that lead acid battery failures account for more Uninterruptible Power Supply (UPS) system failures than all other non-personnel related causes combined. While some of this is due to incomplete, overdue or improper maintenance, the central issue is lead acid technology used in the batteries most commonly used for UPS systems.

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 are highly reliable but extremely large, heavy and maintenance intensive. 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 a very expensive, heavy and highly space-consuming separate battery room requirement when using this technology.

Fig 1. Typical large FLA UPS battery room.

VRLA batteries do not share the size & weight of their FLA cousins. They are more compact, lighter, and much cheaper than FLA batteries. But VRLA batteries also do away with the *reliability* of their FLA counterparts. VRLA batteries are an order of magnitude less reliable and less predictable than FLA. The inability of these sealed cells to add water leads to *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 render it inoperable. For most commonly purchased UPS batteries, this will generally take place in as little as four or five (4-5) years.

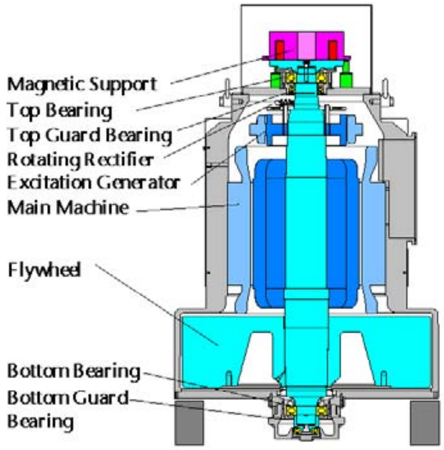
Fig. 2 Failed VRLA battery

Flywheels – the Original Bridge Technology

Flywheels have been around since the dawn of man. Even for UPS & CPS technologies, flywheels have been in use for at least three decades. Many have worked very reliably in industrial applications, despite shortcomings in size, efficiency, cost or maintenance. Today, flywheels for UPS application can be divided into low speed and high speed types. Low speed flywheels might be said to be those products relying on conventional bearings and spinning at speed under 10,000 RPM. For these designs, the user must primarily contend with the cost and downtime of bearing replacements. These replacements typically occur anywhere from 2.5 to 5 years from point of installation or last replacement. High speed flywheels, on the other hand, generally use magnetic "air" bearings and generally do not require bearing change-outs. So that cost is mitigated. However, the complexity of controls, additional support systems, and potential hazard of their high speed rotors (which can hit speed of 30,000 to 60,000 RPM) can make reliability a major concern.

Fig. 3 Low Speed Steel Flywheel

Courtesy of Piller Inc, NY



Notwithstanding all of the above issues, flywheel CPS and UPS systems today represent over $1,000,000,000.00 in installed sales. Again, these are all Bridge applications, meaning only 10-15 seconds of reserve are needed to transition the critical loads to genset power. Clearly by these dramatic figures, UPS Bridge applications are well proven.

Nickel Metal Hydride Bridge systems

Today, a new Bridge technology has arrived. It is Nickel Metal Hydride (NiMH). NiMH is completely proven in rigorous HEV (Hybrid Electric Vehicle) applications as well as consumer laptop and cell phone use. With some similarities to Nickel Cadmium batteries, used for highly reliable diesel genset starting, NiMH has notable differences. NiMH has shown itself to have nearly unlimited cycling capability in typical UPS applications. This is clearly demonstrated by the hundreds of thousands of hybrid electric cars charging and discharging each day.

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

A key difference between Lead Acid batteries and NiMH for Bridge applications lies in the potential size & weight reduction at required bridge reserve time. Lead acid batteries will require the same size at ~3 minutes reserve that they need for 15 seconds reserve. This is directly tied to the electrochemistry. But NiMH batteries at 15 seconds are just ¼ (or less) the size of those required for several minutes reserve. This makes a 15 second NiMH bridge system more compact and lower in installation cost than flywheels.

Other Considerations

Beyond the improved predictability, space advantage and lower failure rates exhibited by NiMH, there are several other advantages of this technology over flywheels. First & foremost is maintenance. Flywheels are known to have both scheduled as well as unscheduled bearing replacement issues. Like the NiMH batteries on your laptop, UPS NiMH are virtually maintenance free. No bearings to change, no complex controls or critical support systems to maintain. Simple batteries. Unlike lead acid batteries, there are no soft lead terminal connections to re-torque, no cell watering issues, no hydrogen generation or acid spills to be concerned with. By our estimation, this is essentially a 10 year full warranty product with all maintenance as well as 7 x 24 monitoring included. And predictability is excellent, again unlike lead acid battery types.

Scalability

Another major advantage of NiMH over flywheels is in scalability. A one ton or 5 ton flywheel is not particularly scalable when trying to up reserve times from, say, 15 seconds to perhaps a minute or more to handle diesel paralleling complications or turbine co-generation applications. You would literally need to quadruple the floor space (and cost) in most cases. But NiMH batteries simply add modules in the same rack for the majority of applications, making growth for redundancy or capacity an easy matter.

Bridge System Life Cycle Costing (LCC)

For the critical facilities infrastructure user, all costs should be considered before deciding on any UPS DC technology. Below, we have assembled an estimated matrix for a sample 750 KW UPS DC application for standard 15 seconds bridge time. It is important to note that NiMH technology is an order of magnitude higher in reliability than VRLA batteries, higher than flywheels, and about on the order of wet (flooded) lead acid batteries. Obviously, this is a significant advantage when comparing total LCC costs. Below costs assumed over a 10 year period:

	Flywheels	**Sealed LA bat**	**Wet LA bat**	**NiMH bat**
Installed cost	$80 - 140K	$55-60K	$95 - 1150K	$70-90K
Warranty	1 yr – 5 yrs	2 – 3 yrs	10 –20 yr prorata	5 – 20 yrs
Reliability	Fair - Good	Poor	Excellent	Excellent
Maintenance Cost*	$25 - $45K	$65 - $95K	$30 - $50K	0
Monitoring cost	$10 - $20K	$20 - $35K	$20 - $35K	0
HVAC cost	0	$10 - $20K	$10 - $20K	0
Space / weight cost	$5 - $10K	$10 - $20K	$15 - $30K	$5 - $10K
Cycling cost factor	$0 - $5K	$5 - $15K	$5 - $10K	0
Environ/Safety	$5 - $10K	$10 - $15K	$20 - $30K	0
Total, 10 yr LCC:	**$125 - $230K**	**$175 - $260K**	**$195 - $290K**	**$75 - $100K**

* includes 2.5 sealed LA battery changes and 2-4 bearing changes for flywheels. Wet/flooded batteries assume 2-4 maintenance visits per year

Conclusion

NiMH batteries are the technology to watch for bridge applications. They are as simple as sealed lead acid batteries to install, more compact and lighter than any competing technology, can cycle indefinitely, and have excellent temperature resistance so they can operate continuously and reliably at over 100 degrees. They are also more scalable and cost-effective than flywheels, demonstrating total LCC cost less than half any other technology over a ten year period.

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The Author

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