ENERGY STORAGE OPTIONS TO MEET THE FCC KATRINA MANDATE

John P. Gagge, Jr.
Director, Reserve Power Americas & Asia
Engineering & Quality Assurance
EnerSys
Reading, PA 19605

David Shaffer
Director of Telecom Sales - Americas
EnerSys
Alpharetta, GA 30022

INTRODUCTION

The recent FCC mandate requiring extended operability of telecom base stations has caused the industry to scramble to find solutions. This paper will provide an overview of stored energy solutions geared to satisfy these requirements. Using the eight-hour backup time as a baseline, we will illustrate both initial and total cost of ownership costs for three common and one novel approach.

The three common solutions are generic lead calcium VRLA blocks, pure lead VRLA blocks and rack mountable Li-ion solutions. The novel approach illustrated will show how a Hydrogen Proton Exchange Membrane Fuel Cell (PEMFC) and onsite hydrogen storage can be a very cost effective and long-term solution for extended run-time applications.

BACKGROUND

At this year's conference, there are other papers published and presented that provide an extensive background on the FCC Katrina rulings and requirements. This paper will not reiterate these facts, but will illustrate how a user has many different options available to them in order to satisfy the requirement.

Standardization within the industry for DC backup solutions in telecom base stations is almost nonexistent. In most cases, it was left to be defined by the individual carrier or operator, available space within a base station, or in some cases by the design of the hut or cabinet itself. Correspondingly, there are many different solutions that need to be considered and each of these has its own applicability and suitability for an application. In some cases there may be no backup at all at the site, in other cases 3 hours and yet in others, eight hours were built in from the start or initial commissioning.

Typical solutions for this industry and application have been generic VRLA 12 Volt blocks, pure lead VRLA blocks and in recent years Li-ion batteries. A new approach involves the use of a hydrogen PEMFC to provide the backup DC power source. This solution, while capable of meeting the eight-hour requirement, is also capable of running much longer and is only limited by the availability of hydrogen fuel at the site. This paper will touch on this and show how there are new solutions that, in some cases, allow 48 hours of runtime in a space where typical battery solutions can only supply 8 hours.

TYPICAL TELCO BASE STATION APPLICATION

For matters of simplification, we will use five (5) kW as the equipment load for this analysis. Sizing the previously listed solutions, we see the following.

Table 1 – Final Solution Configurations and Costs

	Generic VRLA	Pure Lead	Li-ion	PEM Fuel Cell **
System Voltage	48	48	50	48
Ah per Block/Unit	170	190	180	5kW
# Battery Strings	8	6	6	n/a
Cost per String	$1,200	$1,600	$7,500	n/a
Total Initial Material Cost	$9,600	$9,600	$45,000	$40,000
Total RU's req'd	64	48	24	21
# Cabinets req'd	2	2	1	1

** PEMFC option includes fuel cell engine, hydrogen storage, transient power module and system cabinet
Note – In all of the above, considerations were taken for cold temperature de-rating and end of life performance on all batteries.

COST OF LEASED BASE STATION SPACE

In all of these scenarios, the Li-ion and fuel cell solutions avoid the costs of placing another cabinet at the site. Assuming that a cabinet takes up 22.5 ft^2 there are substantial savings in avoiding monthly leasing costs for the space. This is especially critical as we look at the total cost of ownership for any given solution.

Table 2 – Cost of Leased Space for Eliminating a Cabinet

Lease Rate $/ft^2 per Month	Annual Savings	5 Year Savings	10 Year Savings	15 Year Savings
$2.00	$540	$2,700	$5,400	$8,100
$5.00	$1,350	$6,750	$13,500	$20,250
$7.00	$1,890	$9,450	$18,900	$28,350
$10.00	$2,700	$13,500	$27,000	$40,500

LIFE ESTIMATIONS AND COSTS

In Table 1, we illustrated the space savings associated with the various technologies. A critical factor in looking at the total solution is the expected service life of each solution presented. There have been many papers published on battery life and it is beyond the scope of this paper to re-hash this topic. Instead, we will use the following table show the commonly accepted life expectancies of each solution and calculate the total solution costs for three different life expectancies for the solution.

Table 3 – Lifetime Solution Costs

	Generic VRLA	Pure Lead	Li-ion	PEM Fuel Cell
Expected Life	3 yrs	7 yrs	10 yrs	20 yrs
5 yr life cost	$19,200	$9,600	$45,000	$40,000
10 yr life cost	$38,400	$19,200	$45,000	$40,000
15 yr life cost	$48,000	$28,800	$90,000	$40,000

OTHER SITE CONSIDERATIONS AND COSTS

When looking at total cost of ownership, several other factors must be considered. One potentially large cost factor is the requirement for air conditioning of the cabinet. Heat is a killer of lead acid batteries, and the battery life halves for every 10°C above a 25°C baseline.

In the other non-lead acid solutions, heat does not have as dramatic of an effect on performance or life. Ranking the solutions in order of temperature resistance (least to best) shows generic VRLA, pure lead, Li-ion and PEM fuel cells. In a generic VRLA application, it is prudent for users to try to maintain the 25 °C operating environment all year long; this is the environment that will provide for the longest battery life.

The chemistry of the Li-ion solutions enables them to be stored and operated at temperatures up to 40°C without degradation in either performance or life. Raising the air conditioning set point to 40°C not only saves on energy costs to run the air conditioner, but also saves on wear and tear on the air conditioning compressors. A typical air conditioner compressor will last for 3 – 4 years operating to keep the ambient temperature at 25°C. Moving this to 40°C will reduce compressor usage by 50% and eliminate the $1500 expense for replacement of a standard ½-ton A/C compressor.

In the PEM Fuel Cell solution, there are no requirements for air conditioning. This eliminates the costs to purchase, maintain, operate and repair the air conditioning system.

MONITORING AND TESTING COSTS

Another topic of heated debate and discussion amongst many users and manufacturers is that of routine battery monitoring and testing. In some analyses, these costs are overlooked, as they are typically a maintenance expense and not a capital expense item. Nonetheless, they need to be factored into any total cost of ownership analysis.

Monitoring

A user's first option is to utilize some form of battery monitoring system. This monitoring system will measure, record and in some cases validate data from the batteries. These monitoring systems are many times provided by third parties and bolt onto the battery system.

Costs for these systems on the lead acid solutions run from a low end of $2,500 to upwards of $10,000 depending on the user specified options and system complexity. For our specific solutions (generic VRLA and the pure lead), we would expect a user to see a $5,000 cost for the monitoring systems.

The Li-ion batteries have a level of built in diagnostics that can be compatible with the other commonly used monitoring systems. Therefore, the costs associated with monitoring the Li-ion solutions are lower, and generally in the neighborhood of $1,000.

It is generally expected that the monitoring systems will have a 15 + year life and would not need to be replaced over the lifespan of the site.

The PEM fuel cell solutions include on board monitoring and diagnostics and do not require any additional purchased, monitoring or testing. External contacts are provided that allow integration into other existing system alarms or monitoring at the customer premises. The only serviceable item inside the fuel cells is a filter that a user replaces based upon the actual runtime of the units.

Testing

The other option available is to periodically test the batteries for demonstrated performance. This type of routine testing is generally done onsite and by a third party.

Market rates for onsite battery testing run in the neighborhood of $425 for the initial string tested and an incremental $115 for each additional string at the same location. Over a 15-year period, this periodic capacity testing can result in costs as high as $18,000 for the lead acid battery solutions. When factored in conjunction with the fact that while being tested, the system is without battery backup power, we have found that users often choose monitoring over routine capacity testing.

MAINTENANCE COSTS

In addition to any monitoring or testing, each solution has normal maintenance protocols that must be followed. IEEE publishes recommended practices for batteries and every manufacturer also maintains and publishes minimum requirements for battery maintenance. Such items as re-torquing of connections, visual inspections and in the case of the fuel cell solution, filter changes based upon actual run time of the unit. The lead acid maintenance usually takes about two hours, costs approximately $150 per site, and is done twice a year. The PEM fuel cell is maintenance free with the exception of the filter replacement (as mentioned above). For the purposes of this analysis, we conservatively estimate that the filter changes ($50 filter cost + $150 travel & labor) are performed every two years and are not combined with any other site maintenance. Cost schedules for the various solutions are offered below.

Table 4 – Yearly Maintenance Costs

	Generic VRLA	Pure Lead	Li-ion	PEM Fuel Cell
Yearly	$300	$300	$0	$100
5 yr costs	$1,500	$1,500	$0	$500
10 yr costs	$3,000	$3,000	$0	$1,000
15 yr costs	$4,500	$4,500	$0	$1,500

PEM FUEL CELLS

While invented in 1839, it is only recently that PEM fuel cells have started to penetrate the commercial extended runtime markets typically occupied by batteries or diesel generators. The evolution of their designs has come to a point where they are rugged, scalable and capable of being mass-produced. In this analysis, we have focused on the FCC mandated 8 hr backup time and all costs reflect battery sizing to meet this requirement. An additional point to note is that the PEMFC solution is capable of being refilled during the 8 hours it is running and extend the backup time. With additional hydrogen storage, runtimes could be extended even longer.

The run time of a fuel cell is only limited by the availability of fuel. Utilizing high-pressure tanks (350 bar or 5000 PSI) a user can safely store 48 hours of fuel at their location. An additional benefit of these high-pressure tanks is that there is a growing list of gas handling and supply companies throughout the world that will field refill them. There is no need to swap tanks or K bottles in the field.

By utilizing a compact, energy dense design, users can maximize their available real estate and in some cases install the fuel cell above existing equipment without taking any additional floor space.

Another factor that can favor fuel cells is the fact that they do not age unless they are in operation. When not used they simply sit without consuming any energy or aging any system components. There is a periodic system check that is performed every month or so, but the duration is under 2 minutes and fuel consumption is negligible. In effect, it could be considered a solid-state device with a 20-year life.

This is in contrast to batteries where, whether they are used or not, they continue to age and degrade in performance. In all solutions, including generic VRLA, pure lead or Li-ion, even if they were not used over their expected life, they will have to be replaced because of the natural aging process. Fuel cells are not susceptible to this.

TOTAL COST OF OWNERSHIP

As we have illustrated, there are many factors to be considered when evaluating the total cost of ownership for an 8 hr, 5kW telecom base station solution. Illustrated in the following summary tables

Table 5 – 5 Year Total Cost of Ownership

5 Year Total Costs				
	Generic VRLA	Pure Lead	Li-ion	PEM Fuel Cell
Battery/Fuel Cell	$19,200	$9,600	$45,000	$40,000
2nd Cabinet Space Costs @ $5/ft^2	$16,750	$16,750	$0	$0
A/C Replacement	$1,500	$1,500	$0	$0
Monitoring	$5,000	$5,000	$1,000	$0
Maintenance	$1,500	$1,500	$0	$500
Total Costs	$43,950	$34,350	$46,000	$40,500

Table 6 – 10 Year Total Cost of Ownership

10 Year Total Costs				
	Generic VRLA	Pure Lead	Li-ion	PEM Fuel Cell
Battery/Fuel Cell	$38,400	$19,200	$45,000	$40,000
2nd Cabinet Space Costs @ $5/ft^2	$23,500	$23,500	$0	$0
A/C Replacement	$3,000	$3,000	$0	$0
Monitoring	$5,000	$5,000	$1,000	$0
Maintenance	$3,000	$3,000	$0	$1,000
Total Costs	$72,900	$53,700	$46,000	$41,000

Table 7 – 15 Year Total Cost of Ownership

15 Year Total Costs				
	Generic VRLA	Pure Lead	Li-ion	PEM Fuel Cell
Battery/Fuel Cell	$48,000	$28,800	$90,000	$40,000
2nd Cabinet Space Costs @ $5/ft^2	$30,250	$30,250	$0	$0
A/C Replacement	$7,500	$7,500	$0	$0
Monitoring	$5,000	$5,000	$1,000	$0
Maintenance	$4,500	$4,500	$0	$1,500
Total Costs	$95,250	$76,050	$91,000	$41,500

SUMMARY

A telecom user has many options available to them to solve the FCC mandate requiring eight (8) hours of battery backup. These options start with the generic VRLA blocks that have been used since the early 1990's through a longer life pure lead solution and then into today's solutions of Li-ion and fuel cells.

Lead acid blocks have been used in this industry for decades and have shown to be an appropriate solution for the industry demands. Coupled with new technology breakthroughs such at pure lead chemistries this technology can continue to carry the industry well into the future.

Today's new Li-ion solutions bring with them higher energy densities, some level of monitoring and diagnostics, reduced maintenance and longer life. However, due to recent bad press and relatively high initial purchase price, this technology has challenges to becoming a fully viable commercial success in the industry.

PEM fuel cells with their robust design, high-speed manufacturing capability, on site fuel storage and refilling make them an attractive alternative to examine. When a user then looks at the total cost of ownership, a true picture develops for what the industry needs as a solution. Lastly, the PEM fuel cell, once installed at the site is only limited in run time by the hydrogen that it has available to convert to electrical energy.

In the end, it is up to the user to decide how to comply, what the final solution will be and how they want to spend their capital monies. They will have to decide between short term planning that only meets the minimum requirements, or forward thinking and planning that reaches beyond the requirement and exceeds customers' expectations.