Tech Byte 12: Prevent UPS Failures Due to Bad Batteries

Advanced Battery Monitoring and Recommended Maintenance Practices

Batteries are the low tech component in today's sophisticated power systems. As such, their importance in protecting critical IT infrastructure may be overlooked. However, because battery-related failure is the primary cause of UPS system failure, it's imperative to adopt proactive battery management strategies designed to optimize battery performance and reliability without placing operations in jeopardy due to a potentially failing cell. Proactive strategies that should be considered by facility managers for all critical operations include:

- **Following battery maintenance best practices.** The manufacturer's published recommendations. Publications IEEE – 450 for flooded batteries and IEEE – 1188 for valve regulated lead acid (VRLA) batteries document battery maintenance practices that will enhance reliability.
- **Monitoring batteries.** A battery monitor can provide current ambient temperature, cell voltages and internal resistance readings of the batteries monitored, allowing these conditions to be optimized, thereby utilizing the maximum available life and performance of the battery

Many UPS users do not have a regular preventative maintenance routine in place for their battery systems, or they rely on monitored information that does not give a true indication of individual battery health. Proper service is critical to realizing the rated performance and service life of a battery system, regardless of whether it is a flooded cell system or VRLA type. To understand why battery system maintenance and monitoring are critical to successful UPS performance, consider this example:

In a typical UPS system with VRLA batteries, a user may have forty (40),12-Volt batteries connected in SERIES to provide the required back-up power to the UPS's connected load during a failure of utility power (see Figure #1 to the right).

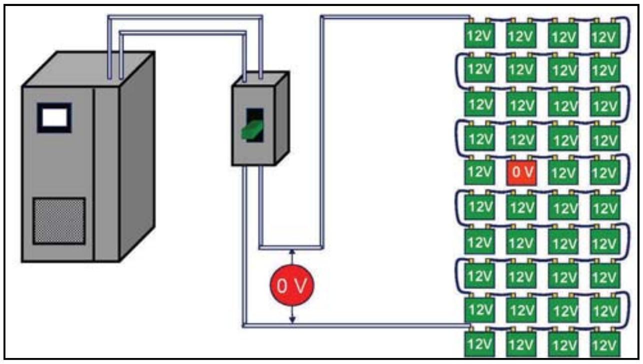

Figure #1—UPS Connected to Battery String

- The most common failure mode of a VRLA battery is an open circuit, due to cell dry-out. One (1) open circuit condition in a SERIES connected battery system results in insufficient voltage supply to the UPS DC bus. In a utility outage situation, this will cause the UPS to shut down on DC under-voltage. Just one (1) cell failure is all it takes.
- Standard battery monitoring capabilities on UPS systems do not give a true reading of ***individual*** battery health. In fact, UPS systems can only monitor status of the battery plant as a whole, and only monitor voltage and current characteristics of that entire battery system. These variables alone can not provide a true indication of battery health during system float charging.
- Some UPS systems offer a battery load test feature, but this only offers minimal timeframe testing that can only identify a bad battery at the latest stages of battery degradation. This is because the test can only last for a fraction of the battery run time rating, as it is not desirable to discharge the batteries to the level where back-up time is compromised, should a power failure event take place in the general timeframe of the test. Live load is connected to the UPS during these tests.

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Predicting whether or not a battery system will perform its intended back-up mission is a major challenge faced by all battery users. There are very few battery users today that have absolute confidence in their back-up system and much of this stems from the difficulty in predicting the health of the VRLA battery.

However, with today's technology, there is no reason why anyone should not have full confidence in their back-up systems. There are both test procedures and test equipment available to accurately determine how a battery is going to perform during an emergency. Unfortunately, a lot of battery users perceive performance testing as both complicated and expensive. However, if one considers the cost and inconveniences surrounding an outage situation, it makes the costs of performance monitoring insignificant.

PERFORMANCE MONITORING

Once we have come to the conclusion that ensuring the integrity of our back-up battery system is important, we must determine how to get there. There are many products available in the market that offer the promise of accurate battery health prediction. To determine the right product, we must understand what information is needed to predict battery health, and then what technology ***offers the ability to most accurately obtain it***. Important information includes:

- Overall Cell Voltage - To verify the charger / UPS rectifier is operating properly
- Individual Cell Voltages - To verify each individual cell is charging properly
- Ambient Temperature - To verify the ambient temperature surrounding the battery is at or near optimum temperature for long life and maximum capacity
- **Internal Cell Resistance -** To verify the state of health by identifying low capacity cells
- **Inter-Cell Resistance** - To check the conduction path integrity between batteries (conductors, terminations) to avoid hot spots, fires, and abrupt shutdowns
- Load Cycles - To check the number and depth of discharges. This information is used to help project battery life and support warranty related inquiries
- Load Current - Document current delivered by the battery during a discharge to determine actual battery capacity

The most critical aspect of evaluating the true health of the battery is a measurement of the Internal Cell Resistance of each individual battery. Why is this measurement important? The most common causes of battery degradation and failure are recognizable by an increase in the internal cell resistance. These causes include internal corrosion, grid growth, sulfation, dry out, and electrochemical and metallic resistance increases *(See pictures #1 and #2 on the following page. Showing examples of a new flooded battery plate vs. aged battery plate. Resistance increase is obvious due to effects of aging)*. Field testing on all types of batteries has proven that if a cell's internal resistance increases to more than 25% above its known good baseline value, that cell will FAIL a capacity test. If we are able to accurately measure and trend this resistance over time, we can detect a battery cell degrading and therefore proactively replace that battery before it contributes to an outage. There have been numerous experiments conducted and technical papers written on this topic by a variety of industry experts that substantiates internal resistance measurement as the proper way to evaluate battery health

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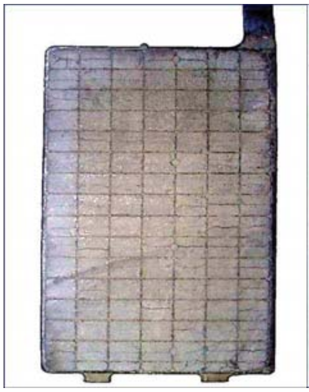
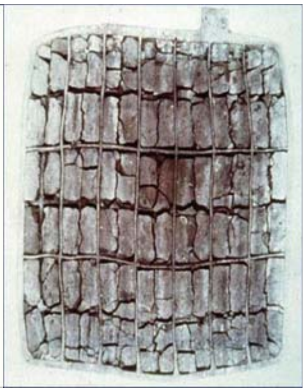
The technology comes into play when we evaluate HOW these internal cell resistance measurements are to be made. Different methods and products exist in the market that inevitably provide drastically different results. Alber Corporation, acquired by Liebert Corporation in 2004, has a patented technology that has proven to be the most accurate method in measuring actual internal cell resistance of all types of batteries. The method they employ is DC resistance measurement. Other products available on the market can not use this patented technology, and instead employ an AC Impedance measurement technology.



Picture #1: New Battery Plate

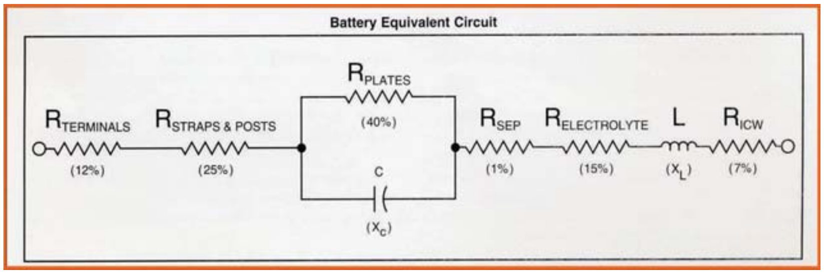


Picture #2: Aged Battery Plate

<u>DC Resistance vs. AC Impedance: Measurement Methods:</u>

The resistance of a battery cell includes all the components in the conduction path through which a discharge current has to flow to deliver energy to an external load *(See equivalent circuit below)*. The battery cell's electrical make-up also includes a huge capacitor (item C in circuit below). What makes AC based impedance measurement ineffective is the fact that the internal capacitance of the cell is in PARALLEL with a significant portion of the conduction path, and therefore, masks the resistance increase that takes place in that part of the path. Experiments performed by both a battery user (New York Telephone, 1986) and a battery manufacturer (Johnson Controls, 1994) using AC instruments have shown that impedance and conductance measurements do NOT correlate well with cell capacity, and they also proved that the higher the test signal frequency, the worse the correlation became.

The reason for this is how a capacitor reacts to an AC test signal. A capacitor's impedance to AC current will vary based on signal frequency. However, at any frequency there will be a current split between the resistive path and capacitive path of the battery plates. This does not allow a true measurement of the plate resistance, which again is the true indicator of battery health. At higher frequencies, the capacitor approaches a short circuit to AC current, and measurements are even more skewed.



During a ***DC test***, the capacitive path becomes an open circuit, meaning the DC test current will pass ***only*** through the resistive path of the battery plates, giving a true and repeatable measurement of the value we are attempting to obtain. Take the mechanical example in Figures #2 and #3 on page 4 for a better understanding: If we were trying to analyze flow reduction in a particular pipe to determine if it is clogged, we would not want to have a bypass path open. We would want to measure the entire flow through the pipe path that is being tested. The DC test method for batteries is similar to the picture that shows the bypass path closed.

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SUPPORT OF BATTERY MONITORING SYSTEMS

Industry support is always something that should be considered closely when evaluating an investment in a particular product or technology. Who better to consider as a resource than battery manufacturers themselves? Two of the largest manufacturers of batteries, Enersys™ and C&D Technologies, Inc., both address ohmic measurement trends as a means to identify battery health status. Although neither of the manufacturers reference a preferred monitoring technology, they both support the idea of advanced monitoring as a way to achieve better indication of battery health.

Enersys™ has been in the business of manufacturing and servicing batteries for over 100 years. In a paper they published entitled "*Ohmic Measurements as a Maintenance Tool for Lead Acid Stationary Cells*", Enersys™ notes the following:

"...In the end, when these ohmic measures are trended over time, insight can be provided into the expected life of a cell…"

"...Ohmic readings where used in a trending mode can be an effective tool to locate troublesome cells that could be deteriorating in performance due to conditions such as electrolyte S.G. change, electrolyte dry out, case/cover/seal/valve leaks, gel deterioration, separator deterioration/shorting, edge shorting, or grid corrosion. These are the type of failure modes that, over time, would cause a gradual change in Ohmic readings that could exceed some "trigger point"…"

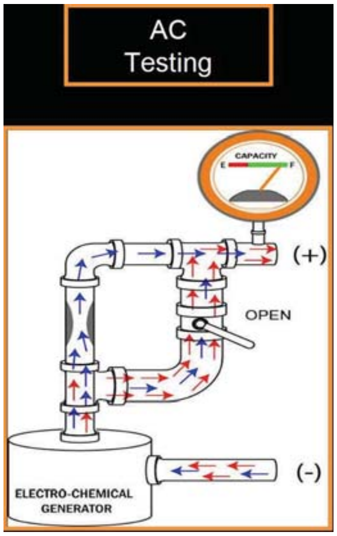

Figure #2:
AC Impedance Equivalent

CONCLUSION

The intent of this information is not to be critical of specific types of batteries. Each application of batteries will have unique demands that require a specific selection. The intent of this message is to bring focus to the fact that maintenance and monitoring of battery systems are critical to achieving desired performance of back-up systems. A break-fix mentality is not acceptable in today's business world, as the impact of outages continues to become more magnified. Solutions that can accurately predict performance and/or component degradation are very valuable in achieving higher availability of critical systems. It is likewise critical to select the proper technology to yield accurate, repeatable results so performance can be predicted.

Eliminating battery failures represents the best way to increase UPS uptime, due to the fact that batteries represent the most common mode of unexpected UPS failures. End users can be confident of battery system performance when they apply the proper technology and perform regular, recommended maintenance.

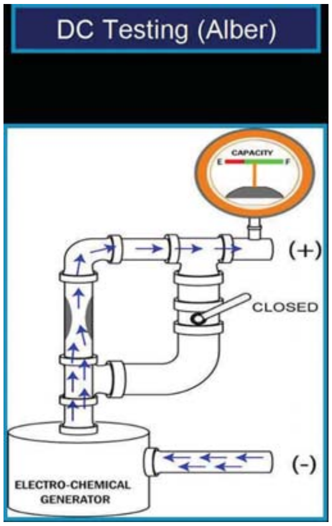

Figure #3:
DC Resistance Equivalent