KEEP YOUR BATTERIES HEALTHY (REMOTELY)

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TODAY'S SPECIALIZATION CHALLENGE

A challenge that most enterprises and service providers face with today's business climate is Downsizing, Rightsizing, Acquisitions, Mergers, etc. We must do more, with less! This is particularly true in the Facilities infrastructure arena. This new business model needs to result in efficient and trouble free operations. This applies to: Computer Centers, Telecommunication Operations, Smart Facilities, Process Control, Manufacturing Operations and more.

As a result of this restructuring, key facility personnel are many times eliminated. Remote monitors of all types are purchased, installed, and presented as the panacea for everything uptime related. The monitoring system salesperson promises that the monitor will solve all problems, and predict all maintenance tasks. Whether or not he or she realizes it, when the manager cost justifies and receives expenditure approval for the monitoring system, his or her job is done. The manager can then move on to other things. The bottom line has been improved. Monitors replace people and their associated costs.

Then, the monitor system is installed and commissioned. It is expected that the system will provide an efficient and predictive tool to eliminate trouble in the future. But many times what we find is that when the disaster occurs, why didn't the monitor predict or catch it?

No one is REALLY watching!

OPTIONS TO CONSIDER WHEN PLANNING YOUR BATTERY MONITORING

Battery Monitoring ensures that the Battery Systems installed with the critical UPS's, and DC back-up power systems are ready to go. Ultimately, someone has to watch the Monitoring System in order to interpret and react to its output data.

There are three general approaches to critical battery backup system maintenance, and each approach can result in a dramatically different impact on network reliability:

1) *Crash, Downtime, Restore*
   Unfortunately, this is what occurs if no maintenance and/or battery monitoring policies are established. Implications of this approach vary from minor inconvenience for non-critical systems to lost customers and $MM for mission-critical installations.

2) *Internalized Monitoring & Preventative Maintenance*
   In order to minimize the chances of a Crash/Downtime/Restore situation, preventative maintenance programs are established internally. These programs include a combination of monitoring systems, and regular manual 'tune up services' based on a set schedule interval. Historically, battery monitors were installed to provide post-mortem data when electrical systems fail, i.e. to understand what happened and what could be done to avoid a repeat occurrence. Providing post-mortem data is an "after the fact" approach - much like an aircraft's "black-box". At a minimum, monitors are installed to provide post-mortem data. (The FAA requirement for black-boxes in aircraft is part of their philosophy of continuous improvement). This certainly offers a more proactive approach, and provides significantly more confidence and inherent reliability in the critical battery backup system.

3) *Outsourced Battery Monitoring Using Predictive Analytics*
This approach builds on #2, and offers an ongoing improvement program that is accomplished by using metrics that answer many questions that cannot be offered by the other approaches. Are my cells/jars/strings going to perform to the IEEE standard? Can I confidently rely on the expertise and timeliness of various individual person(s) looking at the collected data? Are the same methodologies being applied worldwide and managed centrally for my multiple sites? Are there longer-term trends for my particular system compared to industry-wide data? What is the root cause for sudden or trending changes in voltage, impedance, or other values? Why are particular cells/jars/strings getting worse?

With this approach, getting answers to the question "Why is it getting worse?" is the key to taking a pro-active and predictive approach to avoiding disruptions and downtime in the first place.

Outsourced Battery Monitoring can be a cost efficient and valuable tool, and can prevent disasters. Success relies on regular timely interpretation of monitoring data by experts who have a solid understanding of battery electrochemistry and predictive trending analysis. Many times, today's typical efficient company does not employ this specific area of expertise.

PLANNING FOR REMOTE BATTERY MONITORING AND OUTSOURCE OPTIONS

Battery monitoring systems and remote surveillance have their costs, and do require significant planning and organization. Before committing to remote-capable battery monitors, and outsourced remote services, consider the following:

Remote battery monitoring costs need to be compared to the costs of manual maintenance and surveillance of all battery systems that can be remotely monitored. Total in-house costs including maintenance and surveillance labor, tools, test equipment, personnel costs, etc., should also be included. Costs can then be compared with monitor purchase costs, plus outsourced remote monitoring fees by experts. Outsource cost comparisons should be made against the costs of maintaining in-house monitoring and expertise in data interpretation.

Additional costs of downtime caused by system failures, power outages, battery failures, and general disasters should be added into the mix.

TWO BRIEF EXAMPLES OF THE NEED FOR REMOTE BATTERY MONITORING SYSTEMS AND OUTSOURCED SERVICES

A large company in the Rocky Mountains purchased a UPS and Generator system to ensure, that in the event of a power outage, transactions worth millions of dollars would not be lost. This company built 3x redundancy into its UPS battery system to ensure that the three parallel strings of batteries would run long enough, to transition to generator operation in the event of failure of one or two of the three backup strings. A battery monitor was not purchased as part of cost cutting measures.

Two years later, a severe snowstorm hit the area, causing a power outage. During the 15 second transition time from the start of the outage to when the generator would take the critical UPS load (The computer center), three internally corroded batteries exploded when they were called upon to power the UPS. The UPS had no battery power, as each of the exploding batteries was located in a separate battery string. Consequently, the computer center went dark. Many dollars were lost, not to mention more dollars spent to restore the computer center.

This company saw the need for a predictive technology battery monitor and remote battery monitoring services, placed these into operation, and has not suffered this situation since. This company has placed these monitors and outsourced remote battery monitoring services in many major American cities.

Another multi-national company purchased battery monitors for its UPS systems. The remote monitoring and interpretation of data was outsourced. As part of the service, acceptance load testing (full load battery discharge testing), and battery performance evaluation was employed. Many of these services were conducted remotely.

While the battery system performance was adequate for some systems, other systems had reduced battery system performance. This was due to poor individual battery performance. These poor performing batteries under discharge were identified and evaluated by the Monitoring service. Batteries not performing to design standards were replaced and re-tested. In several cases, these tests were monitored remotely

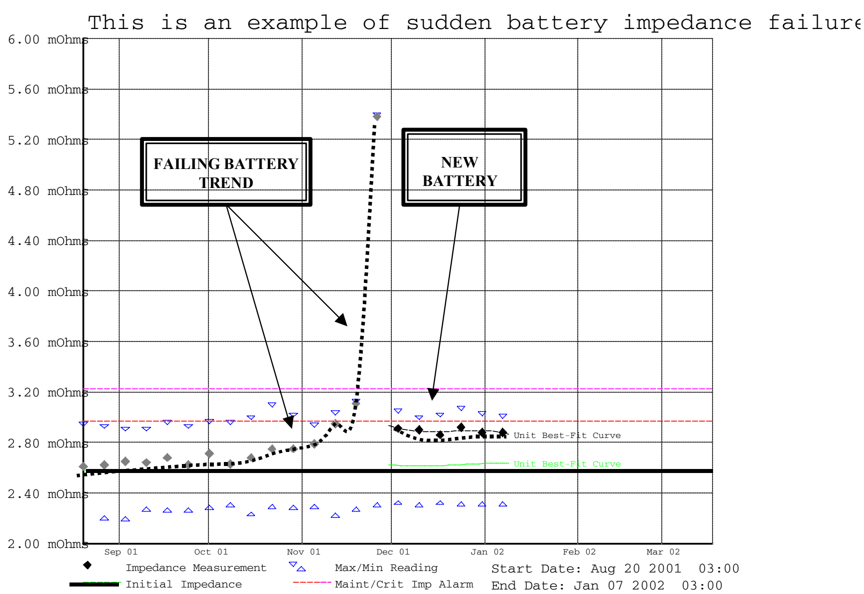
Any battery system that can be remotely monitored by experts will pay off, by the prediction of potential problems before serious alarms and failures occur. This allows for timely fixes, efficient operation, and cost effective maintenance. Total dollars spent on remote monitors and outsourced activity tends to be far lower, yet more reliable and consistent than the old manual methods.

DATA COLLECTION AND INTERPRETATION SCENARIOS

1. SUDDEN BATTERY IMPEDANCE RISE TREND

Importance of remote surveillance on a frequent or weekly basis:

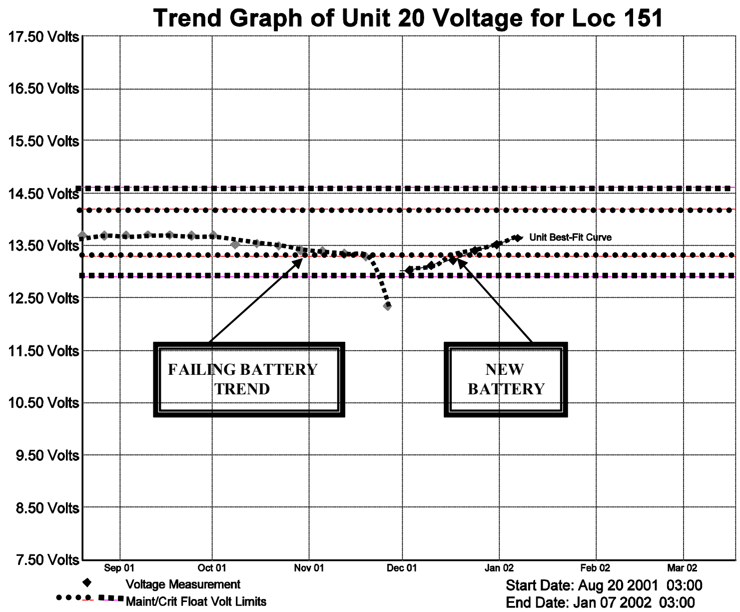
Typically, on-site battery maintenance and inspection of Valve Regulated Lead Acid (VRLA) batteries takes place once a quarter. The graphs of this typical sudden failure point out the importance of weekly monitoring of voltage and impedance, or other ohmic values. As can be seen in the diagram below, the period of the example battery shows the time from normal appearance to failed appearance being about two months:



If this battery string was inspected once a quarter, the odds of finding and correcting this failing jar are not good.

Published battery impedance or resistance specifications state that batteries should be investigated when they rise 20% to 25% above their ohmic values when new. It can be seen by the impedance graph that that this occurred rapidly. Please also note below, that the failing battery suddenly dropped in voltage as it rose in impedance the last week before replacement.

This failing battery could not have been found without weekly surveillance and trend analysis. There is a distinct possibility that the whole battery string would have been of risk of failure during a power outage had this failing battery remained in the string.



Description of the graphs:

Both graphs begin in late August 2001, and the last battery reading is shown in early January, 2002 on the time scale shown at the bottom of the graphs.

On both the impedance graph and the voltage graph, the diamonds show the weekly absolute value of impedance (in Milli-ohms) and Voltage (in Volts.). Note the trend slopes for both the failing period versus the new replacement battery.

This particular string was composed of 40 batteries.

There are two dashed horizontal lines on the impedance graph. The bottom one shows the initial impedance value of the failed battery, when new. Please note that this line has not been adjusted to the new battery, as that is not done until the new battery has been in the system for several weeks, and is stable. It will then be changed to reflect this initial value for trend analysis later in time. The upper horizontal line on the graph is an alarm limit. Typically, it is set at 15% above the initial battery impedance value.

In the case of the voltage graph, the two inner horizontal dashed lines are the upper and lower battery voltage maintenance limits. The two outer horizontal dashed lines are set to upper and lower battery voltage critical limits.

All limits can be programmed into the analysis software used to generate these graphs.

Summary:

Each week, voltage, impedance, or ohmic values are surveyed and analyzed, and trends are identified using a combination of analysis by monitoring software and manual surveillance. While software is capable of limit alarms, and trend rise or fall analysis, manual surveillance by an experienced eye must be employed.

In the case of this example, the user (client) was notified when the trend that is shown was developing. The failing battery was replaced very shortly after the time of the sudden failure shown. The trend allowed for predictive notification before the battery failed completely.

2. AGING BATTERY STRING TRENDS

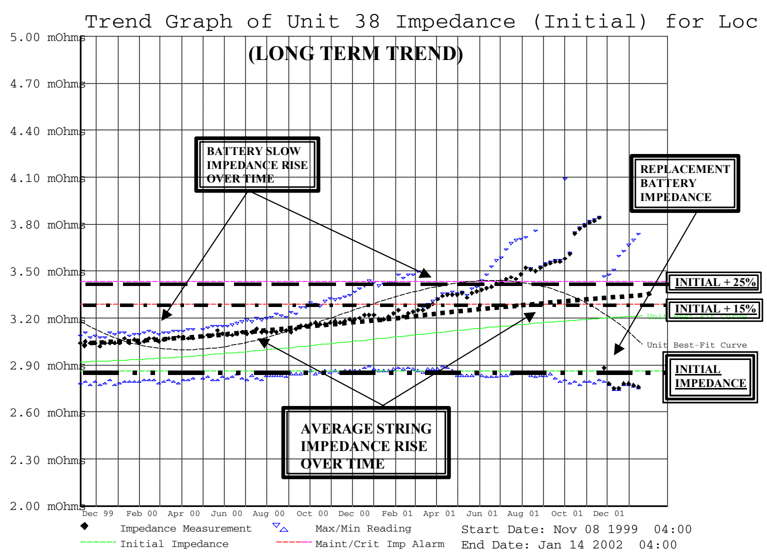
<u>Importance of remote surveillance on a frequent or weekly basis plus long term analysis:</u>

As batteries age and move towards end of battery life, impedance or ohmic trends rise over time. Typically with Valve Regulated Lead Acid (VRLA) batteries, aging can be detected over a period of months or years. Issues involving heat, air ventilation, cycling frequency, and many other related factors can accelerate aging trends.

Aging can usually be detected with the rise in impedance or ohmic trends from string average values when new, to values later in life. It is normal for batteries to rise, as a whole over time. Depending on their environment, this can occur sooner or later.

Published battery impedance or resistance specifications state that batteries should be investigated when battery rise 20% to 25% above their ohmic values when new. It can be seen by the graph that that this is occurring slowly over time.

These trends are difficult to find without weekly surveillance and trend analysis.



<u>Description of the graph:</u>

The graph shown above begins in November 1999 and ends in December 2001, slightly over a two year period. In this particular case, the two year period shown was the second two year period of batteries that had been installed four years. This time scale is shown as the x-axis on the graph.

The diamonds with the trend line show the weekly absolute value of impedance (in Milli-ohms) of battery number 38. It was replaced in late November, 2001. It can be seen that the replacement battery exhibits much lower impedance. This particular string was composed of 40 batteries.

It can be seen that the average string impedance of all 40 batteries is rising over time. Initial impedance levels and alarm points of 15% and 25% are shown with the horizontal lines superimposed on the graph. At the end of the graph, all batteries in this string are above 20%, and approaching 25% above initial impedance values.

<u>Summary:</u>

As this system was monitored and individual batteries were replaced as they needed to be, the average impedance rise of the entire string was observed. While the complete string had not risen to the 25% replacement level, it was recommended that this string be replaced as the batteries that were replaced affected the average string rise.

In the case of this example, the user (client) was notified when the trend that is shown was developing. Coupled with the numbers of batteries that were being replaced (about 20% or so during a four year period, it was recommended that the whole string be replaced. This allowed for an orderly transition and budget time for timely string replacement.

3. BATTERY DISCHARGE PERFORMANCE

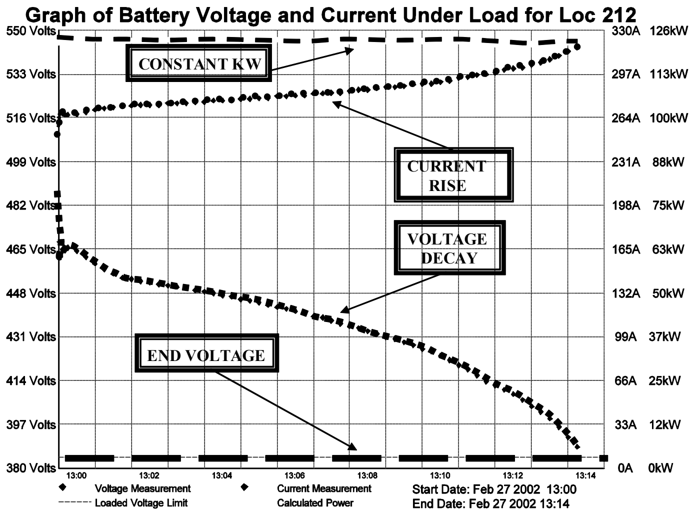
Remote Collection and interpretation of Discharge Results

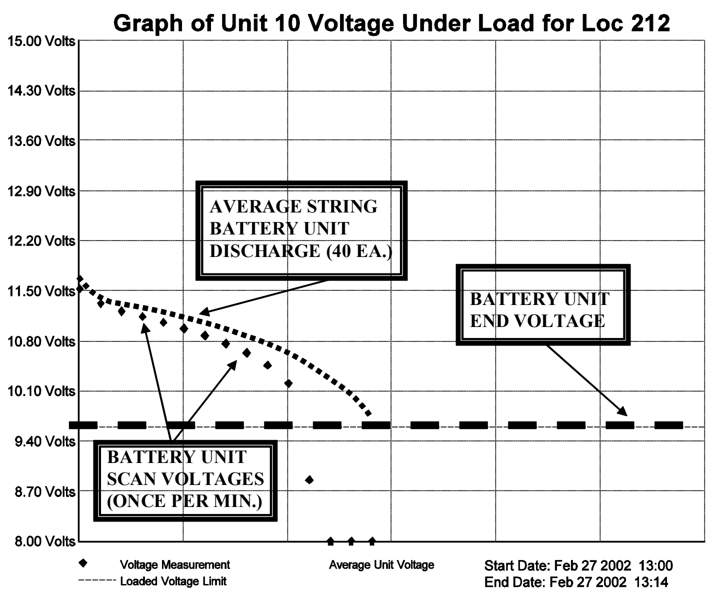
Discharge data can be collected remotely from UPS discharge tests or emergency discharges. This data can be interpreted and results reported. Report data and battery capacity performance is based on IEEE recommended standards. Batteries performing in these events must be checked against the capacity standards and rejected if they perform at less than 80% of their specifications.

Within the IEEE standards (IEEE 1188) for Valve Regulated Lead Acid (VRLA), or the vented battery standards, there are formulas presented, which calculate capacity based on time, load level, and end voltages per manufacturer's specifications.

All of this data can be obtained either by remote means, or by collecting it on site after the test has been performed.

Battery system discharges are based on a predetermined design time. A UPS discharge test can perform to the design time specified for that system, but each battery within the system must also perform. In many cases, all batteries do not always perform to the capacity standards, although the system did perform. These low capacity batteries must be replaced as they could cause problems later on.





Description of the graphs and reports

The first graph shows Battery Voltage and Current Under Load. This particular system contains 40 VRLA, six cell, batteries in a single string. Normal float voltage for this string is 545V. The left side of the graph shows string voltage values, and the bottom of the graph shows time of day during the discharge. The monitor collected voltage and current once a second for the first 15 seconds, and then each 15 second interval for the duration of the discharge. Each diamond shown on the graph after the first 15 seconds is 15 seconds apart, or four are shown each minute. *The duration of this discharge was 14 minutes, 28 seconds.*

The right side of the graph shows current values in one column, and calculated kW in the other column. Please note that while voltage drops, current rises, and kW remains constant at a fixed value.

Note that battery string end voltage was approximately 384V, and battery jar end voltage was 9.6V, or 1.6V per cell (6 cell jars.) The horizontal line just below the battery string discharge data is set to battery string end voltage of 484V (1.6V/cell.)

The next graph shows a low capacity battery #10. Note that this battery dropped below end voltage about four (4) minutes before the end of discharge. Capacity of this battery jar is approximately 70% (failed). This is calculated by the 10 plot points (10 minutes) above the end voltage line, divided by 14 plot points (14 minutes). This formula is in the IEEE standards for determining battery capacity under discharge. 10/14 = 71.4%.

Summary

Full discharge load tests are part of UPS or power system performance to design specifications, both with new systems, and at periodic points in the life of the system. This data can be collected remotely, and can also be obtained during emergency outages. In the case of emergency outages, battery capacity can be determined on all batteries using the basic time of discharge formula presented above. In the example above, it can be seen that this system performed to specifications, however, one battery did not. That battery was considered failed (less than 80& capacity) and was replaced before it could have caused trouble in a subsequent emergency discharge.

Trends and comparisons of voltage and ohmic values during the life of the battery system can be used to predict, or determine when batteries or their connections are failing. It is successful a very large percentage of the time, providing that this data is observed and analyzed on a frequent basis. The discharge test, planned or unplanned, is the key determining factor that will weed out batteries or connections, not found by predictive means.

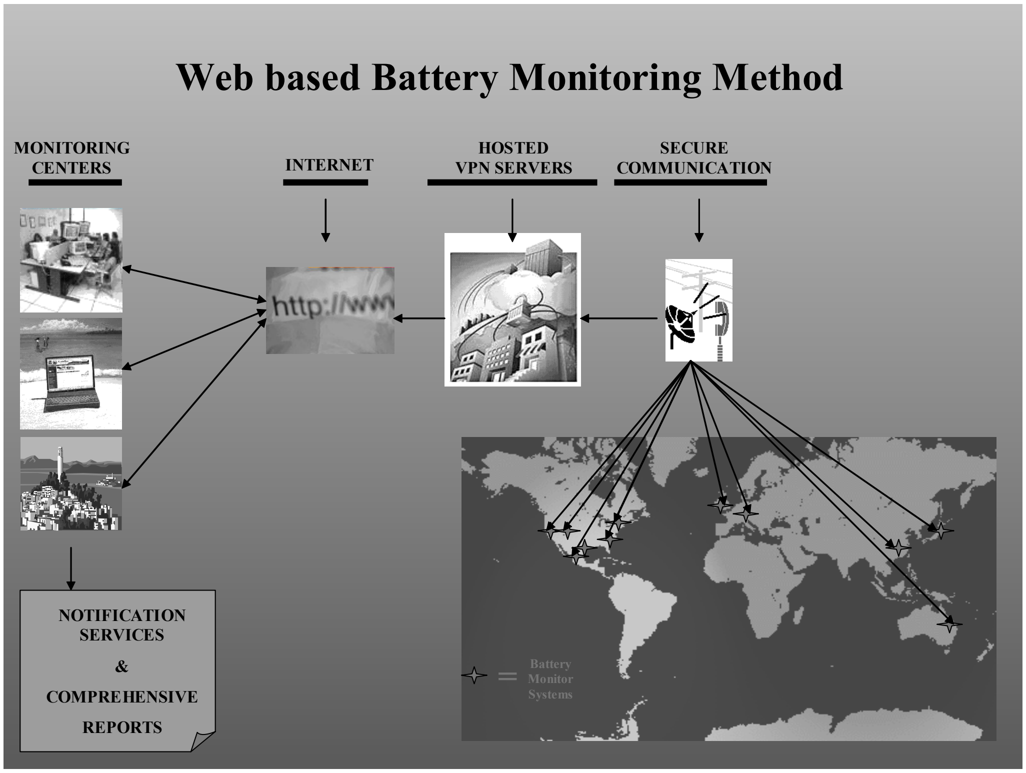
REMOTE BATTERY MONITORING METHODOLOGY – AN EXAMPLE

Battery monitoring systems can be located anywhere in the world where telephone lines are available. Data is collected on a periodic basis (usually once a week) by pre-programmed automatic download. This is achieved by polling local battery monitoring systems on a timed basis, and archiving collected information into a database for each polled monitor. Additional capability exists for the response to local battery monitor alarms, by collecting alarm data, and notifying local monitor users by pager or email.

In this example, the intelligence and hardware used for polling services is co-located in a secure and failsafe location. All polling systems have redundancy built in, and are of course backed up themselves by a completely redundant power and environmental system.

Due to the polling servers being securely located and offering web-based access, they can be accessed remotely from any location on the Internet.

A basic diagram of this system and the method used for the polling service is shown below:



CONCLUSIONS (AKA "IF YOU REMEMBER 4 THINGS FROM THIS PAPER")

- Battery monitoring equipment is only as effective as the people who interpret the data the equipment collects, so there is a natural human interpretive component.
- When evaluating the different approaches to battery monitoring, consider the significant and un-budgetable costs of infrastructure downtime versus the budgetable cost of predictive monitoring.
- Ensure that the architecture allows for all monitors to be accessible from *anywhere* at *any time,* because whoever is assigned as the designated expert looking at the data, is going to need universal and uninterrupted access to the collected data.
- Battery monitoring is a 7x24x365 proposition – ensure that when you commit to this capability, that you have a solid program to rely on internal and/or outsourced experts.