Battery Monitoring: Why Not Do It Right?

Application Note

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BATTERY MONITORING: WHY NOT DO IT RIGHT?

APPLICATION NOTE

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ABSTRACT

Battery monitoring has become a very popular topic, and many companies have either purchased equipment or are in the process of evaluating these systems. This paper discusses why monitoring is important, and what parameters must be monitored. A brief explanation of battery failures is included to support the recommendations presented. This paper is essentially a guide for selecting the right monitor system capabilities required to achieve optimum backup system reliability.

INTRODUCTION

It is now exactly twenty years since the first battery monitor was introduced. In fact, our original patent has expired. The first monitor was primarily designed to reduce maintenance hours and replace inexperienced maintenance personnel.

Since those early days, a lot more has been learned about why and how batteries fail, and a whole new set of battery problems has arrived with the introduction of VRLA batteries.

Today, it has become obvious to users that battery performance cannot be taken for granted. The cost of failures makes the cost of monitoring seem insignificant, especially in large data center applications where even a momentary power glitch to the computers can equate to many millions of dollars in losses.

WHY MONITORING IS NECESSARY

There are many arguments for monitoring, but the most obvious reasons are:

- Increased system reliability
- Cost savings from reduced maintenance hours, and optimized battery life that justifies initial investments
- Personnel safety

INCREASING SYSTEM RELIABILITY

Increasing system reliability by eliminating power outages is obviously a huge cost saving. Sometimes, spending money to save money is a tough argument to prove to company accountants, but when the cost of failure is compared to the cost of monitoring, it almost seems irresponsible not to consider it.

How can monitoring improve system reliability?
Monitoring improves system reliability by detecting battery problems at an early stage, before they can cause an abrupt system failure.

How are problems detected?
Problems are detected by measuring the internal resistance of each cell or module in the system. The resistance of a cell has been proven to be a reliable indicator of a battery's state of health. The only other method for testing a battery's condition is to perform a capacity test. No one can argue the effectiveness of a capacity test, but, unfortunately, because of its cost to perform, many users will not load test their batteries. The chief advantage of a resistance test is that it can be performed automatically, without any test personnel present.

COST SAVINGS

There are three ways that monitoring can provide cost savings that readily offset the initial cost of purchasing a monitor system: by reducing maintenance time, by optimizing battery life, and by reducing test costs.

Reducing maintenance time
The time required to maintain the batteries in a typical small UPS battery cabinet, small telephone office, or power company substation, in accordance with IEEE standards, is at least 25 hours a year. Most of these hours can be saved by using a monitor, and the hours saved will pay for a top of the line battery monitor in two to four years.

Optimizing battery life
Battery life is greatly affected by ambient temperature, excessive cycling, and float voltage. A monitor that assists the user in taking corrective action against any out-of-tolerance condition can prevent premature aging of the batteries. Many users only obtain 50% to 80% of the realistic life of their batteries.

Reducing test costs
Every new battery system must be acceptance tested with a capacity test to prove that it will be able to perform when needed. It is also prudent, especially in applications where financial or safety issues are involved, to perform periodic capacity tests to determine where the battery is in its projected life.

The cost to perform these tests is several thousand dollars per test and requires a lot of setup time. A permanently installed monitor that can log data during a scheduled or unscheduled discharge eliminates a substantial amount of these costs.

SAFETY

A permanently connected battery monitor reduces the need for maintenance personnel to directly contact the high voltages present in most battery systems. If the monitor identifies a problem, then the battery may have to be accessed by maintenance personnel. In the case of a problem, however, the battery will typically be disconnected from the load and the charger, thus reducing the exposure.

UPS systems that have batteries installed in a cabinet are especially hazardous to work with, since there is very little space to access the battery terminals for routine maintenance measurements. And, besides the personnel safety issues, there is also always the danger of someone accidentally creating a problem that shuts the system down.

WHAT PARAMETERS MUST BE MONITORED

Some battery parameters are monitored to verify the battery is being operated in an environment that guarantees optimum life, and some are monitored to track the state of health of the battery. For a monitor to achieve its main objectives, it must, as a minimum, monitor the following parameters:

- **Overall string voltage**. To verify the charger has been set correctly and is operating properly.
- **Cell voltages**. To verify all cells are charging correctly.
- **Ambient temperature**. To verify the temperature environment 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.
- **Intercell resistance**. To check the conduction path integrity and avoid possible fires and abrupt shutdowns.
- **Load cycles**. To check the number and depth of discharges. This information is used to project battery life and settle warranty issues.

Other parameters that are useful in analyzing battery performance are:

- **Load current**. The current delivered by the battery during a discharge is used to calculate the capacity of the battery. It is also useful in parallel string applications to see how the strings share the load.
- **Float current**. The float current drawn by a battery can be useful in VRLA batteries to detect thermal runaway conditions.

WHY BATTERIES FAIL

GENERAL

It should be noted that all lead acid batteries have a limited useful life. The normal failure mode that dictates the end of life of a well-maintained flooded battery is positive grid corrosion. The positive grids lose their mechanical strength and start to break apart. Sometimes before this happens, the grid structure has grown to a point where the paste or active material has lost a lot of contact with the grid.

Both problems lead to large increases in internal resistance that can easily be detected. In fact, it is the authors' belief that, due to the predictable decay of flooded cells, internal cell resistance measurements can be used to predict end of life. The normal life of a good quality flooded battery is twenty years.

VRLA product today has only about a seven-year life span, and these cells do not live long enough to die of normal positive grid corrosion. The most common problem for their early demise has been a drying out or loss of water in the electrolyte. There are also investigations that indicate that secondary reactions from internal recombination of hydrogen and oxygen gasses may be adversely affecting the polarization voltage of the negative plates and/or accelerating positive grid corrosion. Both problems lead to a loss of capacity.

FAILURE ANALYSIS

The following problems, most of which can be controlled by the user, are the most common causes of premature battery system failures:

Excessive cycling. The cycling capability of a lead calcium battery depends on the depth of discharge. For example, the battery is only capable of 50 deep cycles (the removal of more than 80% of energy), but can deliver 300 cycles for a 25% depth of discharge cycle. A UPS battery which normally only delivers about 25% of its stored energy during its 15 minute rated reserve time can deliver 300 such cycles.

Post seal leakage. A leaky post seal allows acid to migrate up to the post/intercell connection area and cause a connection problem.

Loose intercell connections. Improperly tightened intercell hardware means very high resistance connections.

Low float voltage. This causes sulfate crystals to form on the plate surfaces. Sulfate crystals that harden over a long period of time will not go back in solution when proper voltage is applied and, therefore, cause permanent loss of capacity. This problem shows up as an increase in cell resistance.

High float voltage. This causes excessive gassing of hydrogen and oxygen, and this leads to loss of water in flooded cells, and dryout and potential thermal runaway in VRLA cells. High float voltage also causes shedding of active material from the positive plates. All of these problems increase the internal resistance of the cell.

Low temperature. Battery capacity is diminished at low temperatures. (At 62°F, capacity is approximately 90%.) At low temperatures, a higher float voltage is required to maintain full charge. If the charger is not adjusted properly, cells may be undercharged, leading to the problems described under low voltage.

High temperature. This causes loss of battery life. (Life is cut in half if operated at greater than 92°F.) High temperature also increases float current, which results in loss of water in flooded cells, and dryout and thermal runaway in VRLA cells. These problems lead to increase in cell resistance.

Discharge without recharge. A fully discharged or nearly fully discharged cell will be damaged and possibly ruined if not recharged within 24 to 48 hours.

Overdischarge. This causes abnormal expansion of plates, which can lead to permanent damage and recharge problems. This can happen in lightly loaded UPS systems that experience an extended power outage.

Electrochemical resistance increase. An increase due to problems in the paste or electrolyte. This failure causes the cell to “run out of fuel” and become incapable of delivering rated capacity.

Metallic resistance increase. The more serious and dangerous of the two resistance problems. A high metallic resistance means a problem in the conduction path, which can lead to a catastrophic failure, such as an explosion or a total loss of the current carrying path. The metallic resistance problems can lead to abrupt failures, causing potential harm to equipment and personnel, not to mention loss of power.

FAILURE ANALYSIS SUMMARY

It should be obvious from the above discussion that almost all battery problems can be detected by an increase in the internal resistance of a cell. It should also be noted that intercell connection problems can cause fires and abrupt interruptions. That makes resistance measurements mandatory for applications that cannot tolerate a loss of power.

The only battery test that can provide better information on the state of health of a system is a true capacity test.

Since the internal resistance of a cell can be used to predict its performance, it is important to know what the resistance value (baseline value) of a known 100% capacity cell is, and then periodically compare the resistance value of the cell to this baseline value.

BATTERY SYSTEM MAINTENANCE REQUIREMENTS

Many battery users do not understand what is required to maintain a reliable battery system. They therefore:

- do nothing at all while waiting for the system to fail;
- hire a maintenance service and trust that they know what to do;
- connect the cheapest monitor they can find and rely on it to alarm in time; or, hopefully,
- study the recommendations made by industry experts, such as the IEEE Standards Coordinating Committee SCC-29.

The following sections discuss, very briefly, what the IEEE Standards recommend in the way of maintenance and testing for both vented lead acid style battery systems and valve regulated lead acid battery systems.

By comparing the requirements of the standards with the functions that can be automatically performed with a monitor, it will be easy to conclude that a monitor can save maintenance and test hours. Some maintenance inspections, such as visual, cannot be ignored and must be performed at least once a year.

A permanently connected monitor also obviously raises the battery system reliability by a significant factor, since it is on duty 24 hours of every day of the year.

VENTED LEAD ACID BATTERY SYSTEM (IEEE-450)

Scheduled maintenance inspections. A part of a reliable battery system is the scheduled maintenance program. To be successful, the program needs to be regular, consistent, follow standard procedures, and be well documented. The IEEE-450 Standard requires inspections to be performed on a general, quarterly, and annual basis, and following a special circumstance.

General inspection. (Defined as at least once per month.) General inspections include: float voltage of the string; charger output current and voltage; electrolyte levels; cracks in cells, with leakage of electrolyte; corrosion at terminals; ambient temperature; voltage, specific gravity, and electrolyte temperature of pilot cells; and unintentional battery grounds.

A full function battery monitor can perform all the required measurements.

Quarterly inspection. A quarterly inspection includes all general inspections, plus the voltage of each cell, and the specific gravity and temperature of the electrolyte in 10% of the battery cells.

As in the general inspection, a basic battery monitor can perform the majority of the measurements; however, the owner must take specific gravity and temperature measurements of the electrolyte in 10% of the cells to keep with IEEE requirements.

Note: Although the authors are both involved with the SCC-29 group, we do not believe that specific gravity measurements should be taken more than once a year. Some experts believe these measurements are only required when troubleshooting a problem indicated by resistance or voltage.

Annual inspection. Annual inspection includes all quarterly inspections, plus the specific gravity and temperature of each cell, a detailed cell inspection, cell-to-cell and terminal connection resistance, and structural integrity of the battery rack and cabinet.

Unlike the general and quarterly inspections, a battery monitoring system will not perform all the required inspections as outlined. The owner will be required to perform visual inspections of each cell and inspect the structural integrity of the rack or cabinet.

A battery monitoring system with the ability to perform internal measurements and, more importantly, connection resistance measurements, will save several hours of labor and, in addition, perform the measurements in the same manner each time and document the results.

Special inspections. In the event the battery has experienced an abnormal condition, such as a severe discharge or overcharge, an inspection should be made to ensure that the battery has not been damaged. The inspection should include all inspections performed as part of the yearly inspection. Once again, the battery monitoring system can perform most of the requirements.

VALVE REGULATED LEAD ACID BATTERY SYSTEM (IEEE-1188)

Scheduled maintenance inspections. A part of a reliable battery system is the scheduled maintenance program. To be successful, the program needs to be regular, consistent, follow standard procedures, and be well documented. IEEE Standard 1188 requires inspections to be performed on a general, quarterly, semi-annual, and annual basis, and following a special circumstance

General inspection. (Defined as at least once per month.) General inspections include: float voltage of the string; charger output current and voltage; electrolyte levels; cracks in cells, with leakage of electrolyte; corrosion at terminals; ambient temperature; voltage/temperature of pilot cells; unintentional battery grounds; and visual inspection for excessive jar/cover distortion.

A full function battery monitor can perform most of the required measurements; however, the owner is still required to perform visual inspections to check for jar expansion that may cause jar/cover leakage problems

Quarterly inspection. A quarterly inspection includes all general inspections, plus measurement of the voltage and internal ohmic resistance of each cell. It also calls for the intercell connection resistance of at least 10% of the total battery connections.

A full function monitor can perform all quarterly inspection duties with the exception of visual inspections, thus saving many hours of manual readings.

Annual inspection. Annual inspection includes all quarterly inspections, plus reading the temperature of each cell, and performing a detailed visual cell inspection and a structural integrity inspection of the battery rack and cabinet.

Once again, a full function monitor system will perform many of the yearly inspection requirements. However, it should be noted that visual inspections still need to be performed by a competent battery technician.

SELECTING A MONITOR

The selection process must consider the following:

- **System reliability**. How are problems detected in the early stages? The system should track the internal cell resistance as well as the intercell connection resistance.
- **What parameters affect battery life?** These include ambient temperature, float voltage, and number and depth of discharges.
- **Labor savings**. How many hours can be saved by not going to a battery site and manually taking battery parameter readings?
- **Personnel safety**. Will the monitor minimize maintenance personnel’s physical exposure to the battery system?
- **Will the system capture all unusual battery events**, such as alarms and unscheduled discharges? These records are invaluable in evaluating system performance.
- **Data storage, trending analysis and report generation**. Can the system store all pertinent data and play it back on demand?
- **Remote access and dial-in/dial-out capability**. Remote access means 24 hours a day coverage, and allows the user to prioritize the visits to a given site.

It is very obvious that, for a monitor to be cost-effective, it must perform most maintenance functions automatically. The monitor must also be able to do some periodic proactive testing on the battery to identify any developing problems. It is also important that a monitor be capable of notifying the battery owner by both a local and remote alarm capability. A communications capability to access all monitor data and control functions is mandatory for remote battery sites.

BEWARE OF THE FLUFF (THINGS THAT CANNOT BE SUBSTANTIATED)

There are a number of monitor systems on the market today that only monitor one or two parameters, yet claim to be the ultimate system on the market. These systems focus on one or two parameters, such as ac ripple current through the string or a comparison of the mid-point voltages in the string.

These monitor systems do not provide early warning, and they typically do not identify a problem until just before the system fails completely. This is not the time to find out that a problem exists. These systems also do not read individual cell voltages and internal resistances, which means that a lot of manual labor is required to support the system.

BEWARE OF THE PRETENDERS (LOOK GOOD, BUT DO NOTHING)

Some monitor systems have fancy advertising literature, Windows software, etc., but they are basically scanning digital voltmeters. They may eliminate a few maintenance hours, but they do not improve system reliability by detecting developing problems. Without proactive test capability, a monitor will not carry out its most important mission.

SUMMARY

- The importance of battery monitoring, is just starting to be realized
- Potential users need to understand that the only cost effective system is a full function monitor that increases system reliability by identifying early problems and saving maintenance hours.
- Almost all internal battery problems can be detected by an increase in internal cell resistance.
- Personnel safety is a major issue especially in difficult applications, such as high voltage UPS battery cabinets.

CONCLUSIONS

- The right battery monitor system will significantly improve battery system reliability while providing an on-going return on investment.
- A battery monitor must perform a proactive test, display real time battery data, and capture data during a discharge event. If not, it is a waste of money!
- Battery users must understand why batteries fail and what influences the length of battery life; otherwise, they cannot make a sensible decision in selecting a monitor for their application.