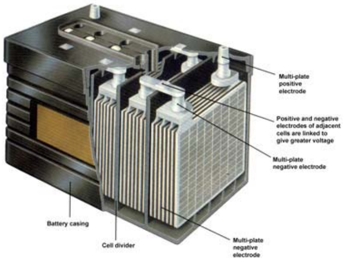
Automating Maintenance of DC Plant, UPS and Outside Plant Batteries



Introduction

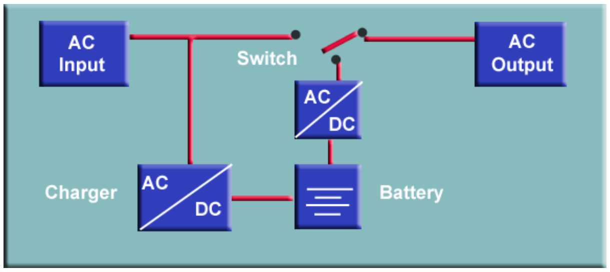
A reality of the modern, competitive, broadband market environment is that providers need to sell a triple-play bundle in order to recapture their large infrastructure investments, while consumers have numerous unbundled choices for their video, data and voice services. Consequently, broadband network operators are being held to very high expectations of quality and reliability. Revenue growth is imperative, subscriber churn is the enemy, and costly downtime is not an option.

Power – A key reliability driver in broadband networks

All broadband enterprises, regardless of their delivery technology, require reliable primary power sources to accomplish their mission. The corporate back-offices, call centers and data centers are the central nervous system of the enterprise. Most often, the facilities that house these operations have redundant uninterruptible AC power systems (UPS) consisting of large battery plants, DC-to-AC inverters, and auxiliary generators. Headends and hub sites, which house critical program content servers and transmission equipment, are usually powered by DC or AC power systems that are also backed up by batteries and generators. In the outside plant of HFC broadband networks, thousands of battery-backed standby power supplies maintain a continuous source of operating power for the nodes and amplifiers that distribute the revenue-generating program content from the headends to the subscribers. Clearly, at every stage of the subscriber fulfillment process from the back-office to the home, a power failure can cause interruption of capability, expensive, panic-driven field-service operations, angry customers, churn, and loss of revenue.

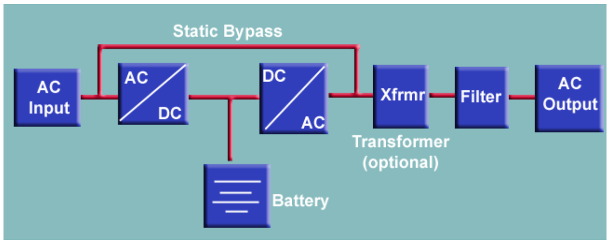
Types of uninterruptible power systems

High-reliability power systems employ redundant technologies to ensure that operations are not interrupted if utility AC power is lost. These technologies can be categorized as follows:



Standby Power Systems – In a standby power system, utility AC power is conditioned by a ferro-resonant transformer and delivered directly to the load. An auxiliary power source, provided by a local battery bank and a DC-AC inverter, is kept charged and waiting for duty. If the primary AC power source is lost, a transfer relay switches the load from the normal utility power source to the battery-backed inverter power source. Most outside-plant standby power supplies have capacities of 1000-2000 watts, and one or two battery strings with three or four batteries in each string. The battery bank is usually sized for 2-6 hours of operation. If a local primary power outage exceeds the run-time of the batteries, a portable generator is commonly brought in to keep the supply powered until primary power is restored. The disadvantage of Standby power is that the amount of time it takes to detect the power loss and switch the transfer relay results in a short power dropout that could be catastrophic to some equipment such as computers. However, in transmission equipment such as is used in HFC networks, this short interruption is usually remediated by the energy storage capacitors inside the network equipment, and is seldom a problem. The advantage of the standby power supply is its simplicity, small size, and low cost.

Uninterruptable Power Supplies (UPS) – Like a standby power supply, a UPS delivers high-reliability AC power to its load. Also like the standby supply, it contains a primary AC power conditioning system and a battery backup system. However, in a UPS, the utility AC power source is first converted to DC which continuously charges the batteries and at the same time powers an inverter which drives the AC load. If primary power is lost, the DC input power for the inverter continues to flow, uninterrupted, from the battery bank. The advantage of UPS power is that there is no transfer relay and consequently no power dropout when primary power fails. The disadvantage is that the AC-DC input power conversion process lowers the overall efficiency and increases the complexity, size and cost of the power system. A typical UPS can range in output capacity from 15kVA to 150 kVA, and is commonly used in conjunction with an auxiliary AC generator. In this case, the UPS only has to run long enough for the generator to start and stabilize, but many operators oversize their battery plants to provide several hours of run time.



DC Power Systems – Increasingly, headend and hub equipment is being designed to operate directly from a DC power source, usually -48VDC. The use of DC power eliminates the cost, complexity and reliability issues associated with input AC-DC conversion in each piece of headend equipment. In addition, an uninterruptible DC power source can be much simpler than either a UPS or a standby power source. In a DC power plant, primary AC power is converted to DC and conditioned by a precision

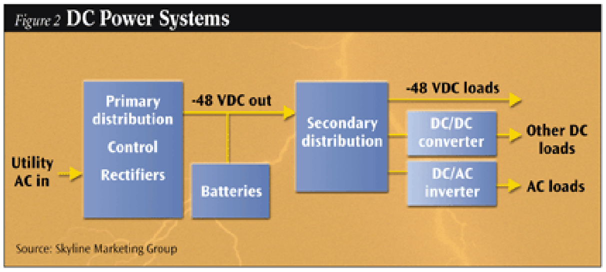


Figure 2 DC Power Systems

Source: Skyline Marketing Group

rectifier unit. The regulated output of the rectifier drives the DC load and the backup battery plant in parallel. The rectifier continuously adjusts its DC output voltage so that a small amount of 'float' current keeps the batteries from discharging. In the event of a primary AC power failure, the batteries will provide an uninterrupted source of DC power to the load. An auxiliary AC generator is usually used to backup the primary utility power source so that power is maintained long after the batteries are fully discharged.

Batteries – Safety net for uninterruptible power systems

The common thread that weaves through all of the leading power reliability systems is batteries. It is essential to be able to store enough electrical energy right at the power supply so that the output of the power supply continues without interruption under all conditions.

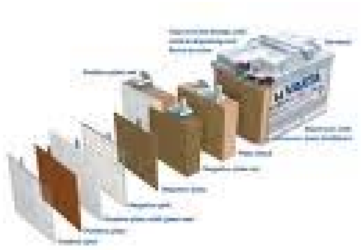
It is ironic that batteries, a 200 year-old technology, is a growth industry and an enabler for popular alternative energy systems such as solar and wind. Thus, it is informative to know a tiny bit about battery basics.

In 1800, Allesandro Volta developed the first practical device that we would call a battery today. In 1859, Gaston LaPlant invented the lead-acid battery cell, and by the mid-to-late 1800s tens of thousands of battery cells were powering telegraph networks around the world. We are still using these basic battery technologies 150 years later.

This device we call a 'battery' is really a collection of voltage-generating electro-chemical cells. A cell is most commonly implemented as two electrodes made of dissimilar metals bathed in a current-conducting electrolyte solution. The voltage that the cell produces is determined by the electrochemical properties of the metals and the electrolyte, while the amount of current it can deliver is proportional to the surface area of the electrodes in contact with the electrolyte. In the case of a lead-acid battery, the "open circuit" voltage of a single cell is 2.1 volts, but several cells are commonly packaged in one “jar” or “monobloc” to produce multiples of the cell voltage. The best known example of a monobloc is the common automobile starting battery which produces 12.6 volts.

A typical lead-acid cell is called a “secondary cell” because it can be recharged by applying an external current to it. The charging process “forms” the cell’s electrochemical state such that the cell will return most of the charging energy when a discharge current path is connected to its terminals. The ability to repeatedly charge and recharge a cell is a distinguishing factor from “primary cell” battery technologies that we commonly work with, such as carbon-zinc and alkaline, which are not rechargeable. Other, more recent, secondary-cell technologies include nickel-cadmium (NiCd), nickel-metal hydride (NiMh), lithium, lithium-ion (Li-ion), and lithium polymer (LiPo). Each of these battery technologies has its distinct advantages, which are usually expressed in storage-capacity, performance under extreme environmental or other design-specific conditions, cost, durability, size and weight. Some of the newer technologies, although attractive from a performance standpoint, are inherently unstable and require embedded electronics around each cell in order to tame them. Yet other technologies still in the laboratory promise great improvements in all areas, but for today and in the foreseeable future, lead-acid reigns supreme where high capacity, reliability and stability are essential.

Types of lead-acid batteries

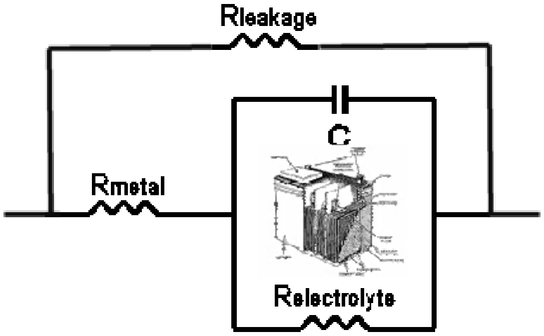


The first lead-acid batteries consisted of stacked, separated plates of treated lead immersed in a “jar” of sulphuric acid. These “wet” or “flooded” cells” have been proven to be very durable and the basic construction is still used today for applications such as telecom COs and power generation sites, which require high-reliability and long service-life in hostile environments. Wet cells, also called “Vented Lead Acid Cells”, have usable life spans of 20 or more years, can supply large amounts of current for long periods of time and they tolerate deep discharges quite well, but they are large, heavy, (as much as 1000 pound per cell), and expensive. The biggest enemy of flooded cells is evaporation of the electrolyte, which can cause the plates to become exposed to air and develop an insulating layer of lead-sulphate that prevents proper electro-chemical performance, even if the electrolyte level is restored. In addition, flooded cells can emit corrosive fumes and explosive gasses. Because of this, flooded cells require special housing (re-enforced and some times indented flooring), along with inert material barriers to contain spills) and maintenance procedures. Flooded cells must be mounted in an upright position to prevent an acid leak.

A more compact and easier to maintain version of lead-acid battery is the valve-regulated lead-acid (VRLA) battery. A VRLA cell, monobloc, or jar is fitted with a special seal that keeps the products of electrolyte evaporation inside the cell. The seal has a pressure relief valve that only allows the battery to vent to the outside if the pressure inside the cell exceeds a threshold that is beyond what would be expected in normal operation. Things that can make the VRLA vent to the outside include extended high-discharge currents or excessive charge currents. VRLA batteries typically last seven to eight years and can be mounted upright or sideways and do not require “watering” as with Flooded or Vented Lead Acid cells.

An increasingly common variant of sealed cells are called “gel-cells” or “AGM” cells. In this type of cell, the acid electrolyte does not “flood” the plates in a bath of liguid, but is either presented as an immobile acid paste between the plates, or as a fiberglass mat that is saturated with the acid electrolyte (AGM = Absorbed Glass Mat). AGM and gel-cells require very little maintenance and don’t have to be mounted in any specific orientation.

Factors affecting a battery’s capacity



Ideally, a battery cell would deliver its theoretical cell voltage no matter what the load current. In practice, batteries are not ideal, and their performance is impaired as though there were some resistances inside the battery. In fact, there are three very important resistances that affect performance:

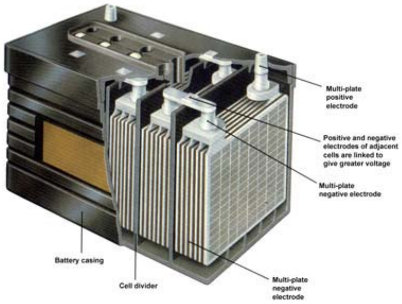
- A real series resistance due to the metallic losses (Rmetal)
- An “equivalent” series resistance that expresses the limitations of the electrochemical generating process (Relectrolyte)
- An “equivalent” parallel resistance that expresses the tendency of the cell to discharge over time if not connected to a charger (Rleakage)

For our immediate purposes, we’re most interested in the total of Rmetal and Relectrolyte, as these determine the maximum current the cell can deliver under any circumstances. Rmetal and Relectrolyte are commonly about equal to each other, with a total value that varies inversely with the current-producing capacity of the cell. Typical values of total internal resistance range from as much as 0.06 ohms for a typical 6-cell monobloc to below 0.0005 ohms for a large single-cell jar. These resistance values are commonly expressed in their inverse form, called “Conductance”, with units of “Mhos”. Common Conductance values thus range from less than 150 Mhos for a multi-cell monobloc to well over 2000 Mhos for a large single-cell jar.

Due to the nature of the electrochemical process, the transient response of the cell's output voltage lags any instantaneous changes in charge/discharge current, and so we can also infer that there is an equivalent capacitor inside the cell (C). By stimulating a cell with AC currents and observing the response, it has become well-accepted that the internal capacitance of a lead-acid cell also varies in almost direct proportion to the cell's current producing capability. When a cell's ohmic properties are measured with AC test signals, the complex measurement result is expressed as "Impedance", or its inverse "Siemens".

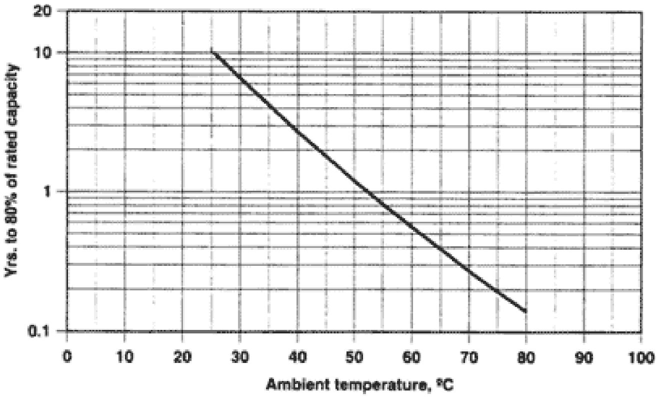
A cell's current-producing capacity declines during a load event, causing the voltage to drop over time. This performance is typically expressed as the number of hours the cell can deliver a specified load current before the output voltage drops to a specified level, typically 80% of its fully-charged unloaded voltage. As an example, a typical sealed 12.6V monobloc might be rated for 100 amp-hours. This means that, with a continuous 100 amp load, the battery would be expected to deliver at least 10V for at least one hour. In contrast, large flooded cells often have capacities exceeding 1000 amp hours.

The primary factor that determines the amp-hour capacity of a cell is the surface area of the plates in contact with the acid electrolyte – more is better. To exploit this, sealed batteries, which have to be small, light and yet deliver very large instantaneous currents (500-1000 amps to start a car) are usually made with thin perforated plates that allow maximum electrolyte contact area with minimum size and weight. They are great "sprint runners", delivering high currents for a short period of time. The tradeoff is that the thin, weak plates do not perform well under sustained high currents and can warp and short-circuit to the closely-spaced adjacent plate. On the other hand, flooded



cells are usually made with thick, solid plates. They can't supply as much peak current as some of their sealed counterparts, but they're great "marathon runners" that can take a lot of abuse.

Battery state-of health



When we refer to a battery's "state-of-health", we're referring to where it is in its useful service life expectancy. "Service life expectancy" is typically based on manufacturer's warranty terms. For warranty purposes, manufacturers typically specify the minimum number of years after purchase during which the battery will deliver at least 80% of its rated amp-hour capacity. They further de-rate the warranty based on storage environment and charge discharge activity. Flooded cells are usually expected to last 15-25 years if properly stored and maintained, while sealed multi-cell blocs can last 5-8 years under "ideal" conditions. However, due to non-ideal storage, use and maintenance, it is not uncommon for batteries to last much less than half of their rated life expectancy. For instance, battery warranties are based on a storage temperature of 77ºF. For every 15ºF rise above 77ºF, the service life is reduced by about one-half. Warranties also include de-ratings for how many times the battery has been discharged by 30%, 50% and 100%. As a practical matter, it is commonly known that a single deep discharge can reduce the useful service life as much as 40%.Premature battery failure can also be caused by charger abnormalities. For example, overcharging can cause "dry-out" of the electrolyte and oxidation of the plates, while undercharging can cause sulphation of the plates. Excessive AC ripple on the DC charging current is like continuous micro-charge/discharge cycles, leading to battery heating and subsequent deterioration. Common indicators of state-of-health include float charge current and ohmic measurements.

State-of-health measurements

There are measurement metrics that can be used to determine a battery's state-of-health, some of which are difficult and expensive and some of which are simple and inexpensive. The most obvious measurement that would come to most minds is voltage, but voltage only tells an accurate story about battery health when the battery is under a full load. Automobile shops use a simple clamp-on meter that has a built-in load of 100 amps or so. The load is applied to the battery for about 15 seconds while the voltage decline is monitored. This type of load test is a good indicator that the battery can supply short-burst starting current, but it doesn't tell how well the battery will hold up under long-duration lower load stresses. For large fixed-battery installations, the "gold standard" of health testing is to bring in a large, fan-cooled "load-bank" that that puts a full load based on the design criteria of the battery on the plant for several hours while logging voltage measurements for each individual battery during the discharge. Load testing is universally recognized as the best way to know how a battery plant will hold up under actual load conditions, but it is difficult, very expensive, intrusive, provides only a snap shot in time, requires a backup power source while the battery plant is off-line, makes the batteries unavailable for service for up to 72 hours after the test is completed and so is seldom done more than once every couple of years.

Even if a load test is performed annually, it is well known that VRLA batteries can deteriorate deeply over a period of just months, sometimes weeks. The most common failure mode for a VRLA cell is an open-circuit, which can be disastrous in a series string of cells. A plant that is intended to run for hours might not even run long enough for the auxiliary generator to spin up and come on-line. For this reason, it is important to make regular measurements on the battery plant using an easy, reproducible and inexpensive method. For this, most power engineers now recognize that making measurements of each cell's "ohmic properties" can have great value.

Ohmic testing measures a cell's internal resistance (Rm + Ri), which is the key factor limiting its ability to deliver current. Ohmic test equipment does this by stimulating the cell with relatively small, accurate, repetitive current pulses while monitoring the cell's instantaneous voltage change during each current pulse. The instrument then performs some math on the resulting measurements to calculate the equivalent cell resistance. Some instruments use DC for this test, while others use low frequency AC signals. The result is displayed in units of "mhos" which is the inverse of resistance, or "Siemens" which is the inverse of AC impedance. Either technique will provide a valid indication of changes in battery condition.

Other periodic tests that can provide valuable insight into the battery's health and state of charge are:

"Float" Current" – A properly designed charging system will limit the voltage applied to a battery string to the manufacturer's float-charge voltage specification. Battery manufacturers tell us that, once a cell reaches the charger's float-voltage, it will then draw just a small float-current of about 0.025-0.050 per 100 amp-hours of rated cell capacity. As the cell ages, the float-current will begin to rise, going up rapidly just before end-of-life. Measuring the float current can provide an early indication that one or more cells in a string are deteriorating, warn of impending thermal runaway and provide indications that a cell has an open circuit.

"Post-Temperature" – As the cell nears end of life and the float current rises, the cell temperature will rise. As the temperature rises, the cell's voltage drops and it draws more current from the charger. This process is regenerative, often resulting in a catastrophe called "thermal runaway" where the cell gets so hot that it bulges, outgases, and even bursts. Measuring post temperature and float current can provide an early warning of thermal runaway. In fact some operators rely solely on float current measurements as a means of predicting thermal runaway.

"Ripple-Current" – If the charger malfunctions, it can produce large AC currents in the dc charging path. These currents act like mini-charge/discharge cycles heating the battery, shortening its life, possibly triggering a thermal runaway.

Very soon regulatory bodies in the power generation and transmission industries will require ohmic measurements in lieu of load testing.

Management practices that can ensure rated run time and life

Maintenance and management practices to ensure best cell life and performance vary somewhat depending on the type of cells being used. Flooded cells are, in general, very robust and only require periodic inspection to determine that electrolyte level is proper and that no connection impairments or corrosion have developed. At one time, it was common to measure the specific gravity of the electrolyte in each cell as a measure of state-of-charge, but conventional wisdom is abandoning this practice in favor of float current measurements. Float current should remain quite steady near manufacturer's specifications during normal, fully charged standby operation, rising sharply then declining to normal after a discharge event, and climbing steadily as the cell nears end of life. Aside from these tests, flooded cells are good citizens.

VRLA cells, including GEL and AGM, are quite a different story. The price we pay for their small size, light weight, and sealed electrolyte is eternal vigilance. As mentioned earlier, VRLA cells can deteriorate quickly, sometimes well within their warranty, and often for no obvious reason. A study of inside-plant VRLA batteries by France Telecomm some years ago indicated that the failure rate in the first couple of years of service was less than 2%, increasing to 40% by the fourth year, and nearly 100% by the seventh year. Thus, it is no surprise that many operators replace all the units in the fifth year of service. Some consider that to be all the maintenance they need, but a large body of actual field experience indicates that a statistically small population of VRLA cells will deteriorate and become useless over a period as short as weeks, even though they are well-within their 5-7 year service life expectancy. With strings of 40 or more monoblocs, each with six cells inside, the statistical likelihood of a single cell failure at any time is significant, and is the cause for very many power-induced outages. They need to be checked frequently, and data trends need to be analyzed. For this reason, the IEEE has established special guidelines for VRLA battery maintenance (IEEE 1188). This standard recommends the following practices:

Monthly – String voltage, string float current, temperatures, ventilation, visual checks

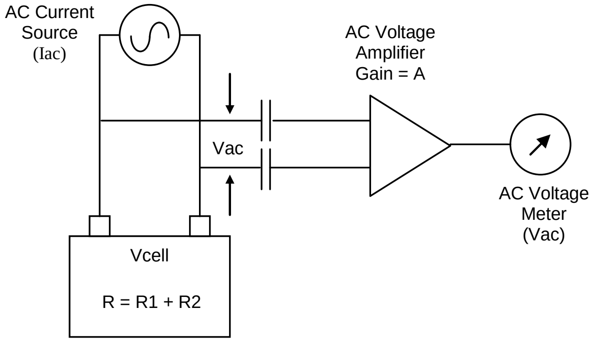
Quarterly – Above plus ohmic measurements, individual post temperatures, interconnection resistance

Semiannual – All above plus voltage of each cell/unit

Annual – Same as semi-annual plus full-load

About ohmic measurements

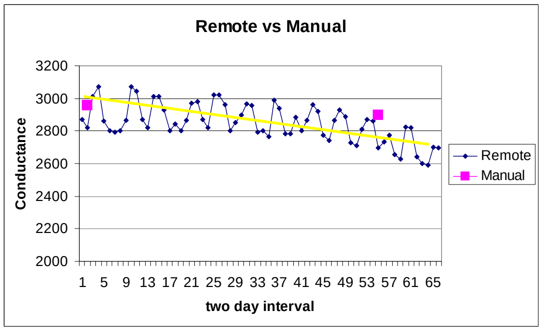
“Ohmic measurements” refers to non-intrusive metrics of each cell’s internal resistance which can be made using portable equipment. Ohmic measurements, if made properly & regularly, have



been found to provide useful trend information that can determine if a cell/battery has more or less than 80% of capacity remaining, providing early indication of a cell’s demise, so that pre-emptive action can be taken. The ohmic measurement instrument stimulates the cell being tested with a precision current waveform and measures the cell’s voltage response to the stimulus. Since a battery has equivalent capacitance as well as equivalent resistance, measurement results can vary with the frequency of the test signal. Some instruments use large DC currents, while others use lower AC currents. In the former case, the measurement result is purely proportional to the cell resistance, and can be displayed as either resistance (micro-ohms) or conductance (“mhos”, the inverse of ohms). If the measurement is made with an AC test signal, the result can be displayed as impedance (ohms) or as inverse impedance (“Siemens”). When the test frequency is very low, say 20Hz, the difference between DC measurements and AC measurements becomes negligible. The advantage of AC measurements is that lower test currents can be used for the test by taking advantage of frequency-selective detection circuits to reject noise and interference. It is thus possible to make an accurate impedance testing device much smaller, simpler and less expensive than a DC measurement device. This is important for permanently installed remote monitoring systems.

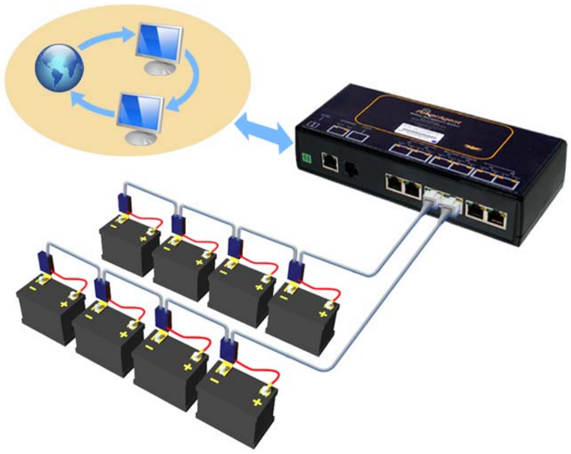
Advantages of frequent ohmic measurements

Ohmic measurements are most valuable when performed frequently enough so that a trendable data set can be assembled. If these measurements are made manually by visiting the site with a portable test meter, the economics usually limit the number of measurements that can be made to a few per year or less. Furthermore, large capacity cells can have internal resistances of less than 200 micro-ohms. As an illustration of how small this is, a 1” long



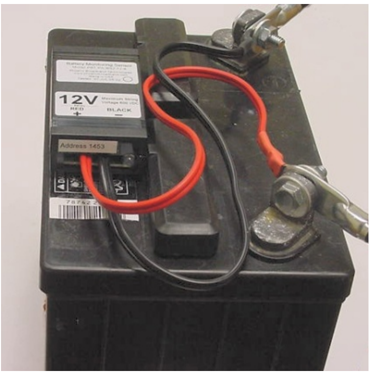
piece of #14 copper wire has a resistance of about 250 micro-ohms. Thus, in a measurement of a high-capacity battery, a spurious resistance in the measurement path equivalent to just 1/10" of #14 wire could produce a measurement variation of 10%. It is thus no surprise that manual instrument measurements, which rely on repeatably excellent contact between the meter probe and the battery post, can vary significantly from one visit to the next, making trendline development very difficult.

Automated management systems



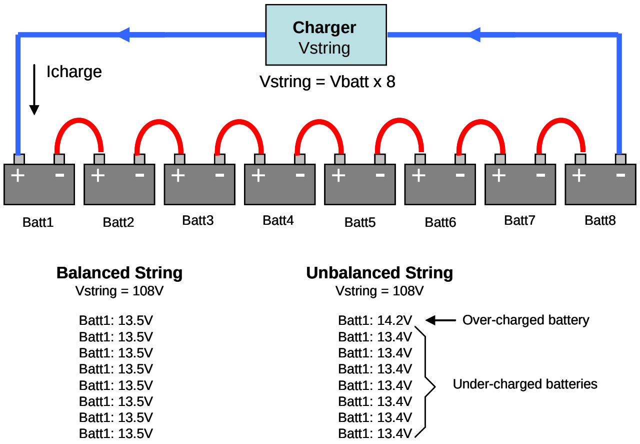
Historically, operators have used manual maintenance techniques to assess battery health and determine end of life, an approach that has been, at best, only partially effective. Manual measurements are typically made with hand-held meters and include individual cell and string voltages, individual jar or monobloc ohmic measurements, string-level float currents, and temperature. In high-capacity cells manual ohmic measurements are affected by probe placement, how hard the technician presses the meter's probes against the battery post, the type of meter, and the technician. These variables can affect the measurement results by as much as 10-15%. Furthermore, these measurements are commonly performed two to four times per year and provide, at best, a snap-shot in time. No data regarding the number, duration or depth of discharges are kept with manual maintenance techniques. In low capacity blocs, batteries can and do fail in between maintenance visits. Consequently, every couple of years, a "capacity" or load test is required to test actual battery capacity. There is clearly a need for easier, more frequent and more repeatable measurements that facilitate reliable trend information that can predict impending failures. This is the realm of automated battery management systems.

Automation provides a holistic approach to determining battery health which is far more effective than manual techniques. By continuously monitoring cell and string voltages, float currents, discharge cycles, performance during discharge, and environmental conditions we have a more complete picture of the battery's environment and the conditions to which it was subjected. Battery manufacturers do not have to speculate as to why the battery failed if detailed records are available. Operators can predict failures weeks or months in advance instead of reacting to failures.



With modern systems operators can instantly know the status of all or any of the batteries across the entire enterprise. For example, if battery room temperatures increase to a point harmful for the battery, the operator will be notified in enough time to schedule maintenance, eliminating possible emergency truck rolls. Ohmic measurements can help operators determine when to replace a battery well before a voltage change would indicate the need for action. Monitoring float currents can predict thermal runaway and allow operators to act before a catastrophic failure occurs.

Charge equalization



In a perfect battery plant, each cell or bloc would have an identical float-charge voltage. In practice, however, there are very slight variations in internal cell-to-cell performance which are Inherent to electrochemical and manufacturing process variations. Since most modern chargers today use constant voltage float charging, these slight cell-to-cell variations will cause slight differences in float-charge voltage, with some cells/blocs having a higher voltage and some a lower voltage. As long as the differences are within an acceptable tolerance the variations do not become problematic. Battery manufacturers tell us that, in a string of two-volt cells, the cell-to-cell imbalance should be kept within 10mv peak-to-valley and in a string of six-cell blocs (12 volt batteries) the variation should be less than 60mv. Introducing a new cell or bloc into an existing battery string can also cause imbalances and can prevent proper charging of the new cell. If left unchecked, bloc-to-bloc charge imbalance in a string can become severe enough to cause sulphation if charge voltage becomes too low, or gassing if too high. In strings of 40 or more batteries, as in a UPS, unacceptable charge imbalances are common. One way to combat charge imbalance is to force a substantial overcharge current through the string, with the expectation that undercharged cells will become fully charged before the other cells are damaged by the overcharge. This method has proved marginally effective in strings of six to twelve cells, but does not work very well with strings of 40 or more 6-cell monoblocs.

A more effective way to provide charge balance is to actively balance charge on each cell or bloc using intelligent charge management systems. This technique is well known in the world of standby outside-plant power where aftermarket battery balancers have been proven to extend service life. Until recently, however, available charge balancing systems have not been effective for long strings of cells. Recent breakthroughs in automated battery management systems not only monitor many metrics of each cell's performance, they also manage the charge balance on each cell in a long string. A bonus of this intelligent equalization approach also provides metrics on how hard the balancing process has to work on each cell so that changes that occur over time can be tracked and trended.

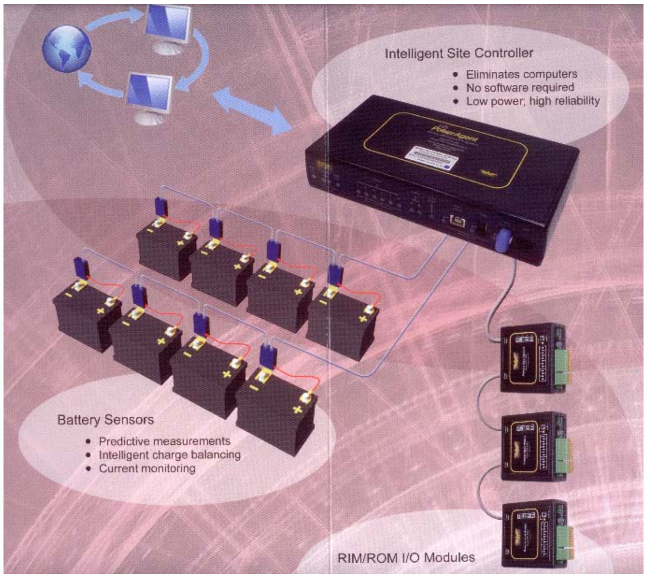
Special monitoring considerations for flooded cells

Flooded cells are inherently more robust than VRLA cells, and so don't require as much day-to-day attention. There are, however, a few very important parameters which, if left unattended, can destroy a 25-year cell in just a few years. Specifically, it is important that the cells be kept properly charged and that electrolyte level is maintained at the prescribed depth, as the cell normally vents gasses out over time. Both of these requirements have traditionally required reqular site visits to inspect and measure the cells.

Battery engineers have long used the specific-gravity of the cell electrolyte as an indication of state of charge. However, specific gravity measurements suffer from vagaries similar to other manual test methods. Due to a phenomenon called “stratification”, the specific-gravity of the electrolyte will vary depending on the depth in the electrolyte where the sample is drawn. This can cause substantial variation from one measurement to the next. The industry is now accepting that float current monitoring is a far more accurate and indicative measurement of state-of-charge, with the bonus that the measurement can be made automatically by a battery monitoring system. In addition, products are now in development that will allow the battery monitoring system to measure and monitor electrolyte levels non-intrusively and remotely. As a bonus, the ohmic measurements, cell voltage measurements, and post temperature measurements provided by an automated battery monitoring system fill out a holistic profile of flooded cell performance metrics.

Other Capabilities of Automated Battery Monitoring Systems

In addition to monitoring many key indicators of battery plant and cell health, some battery monitoring systems also make provision for monitoring power-plant-related equipment and the facilities that house the power system. Accessory devices are sometimes provided to monitor



contact-closure indications as well as DC and AC analog voltages. Other devices can be attached to the system to allow remote control of power or facilities-related equipment. In a typical power facility installation, these capabilities would be used to monitor generator status, fuel levels, HVAC performance, power utility voltages & currents, and many other parameters. Remote control capabilities allow the generator to be remotely turned on for testing, HVAC controls over-ride, and virtually unlimited additional remote control capabilities.

Monitoring system architectures

There are several suppliers of automated battery monitoring systems. Most of these systems were designed for use in data-centers, power-generation plants, or industrial installations. Most are based on centralized measurement units that require “home-run” wiring to each of the batteries in the plant. They often require complex , expensive and reliability-limiting PC servers at each monitored site, and the buyer is usually locked into a proprietary monitoring software application provided by the hardware manufacture.

Recently, a new breed of battery monitoring system, optimized for the telecommunications industry, has emerged. This new generation system employs inexpensive measurement sensors at each cell/mono-bloc, small, simple, inexpensive & reliable solid-state site control units, plug-n-play interconnection cabling, industry-standard SNMP-based management interface, built-in web monitoring interfaces, and complete freedom to interface directly to any enterprise-class network management system. The advantages of tight integration with enterprise software systems enables the ability to gather, database, and trend large volumes of measurement data from hundreds of sites and tens of thousands of batteries. As a bonus, such systems can form the basis of a comprehensive battery inventory tracking system.

Getting the most from a monitoring system

Monitoring systems can provide a great wealth of stored data which can be analyzed and displayed in graphical forms to make identifying abnormal trend lines very easy to spot. A steadily declining battery admittance can be clearly identified using hundreds of data points supplied by automated systems in the same time frame as two manual data points would typically be gathered. With manual measurements this would be nearly impossible. The same argument can be made for float current, voltage or temperature measurements. Automating battery maintenance should be used to proactively schedule site visits. Historically, periodic site visits uncovered battery problems after they occurred. Automation changes the model completely eliminating unnecessary emergency visits and allowing the operator to know what equipment is needed before they visit the site.

Monitoring systems are great at making measurements and gathering data which can be sent remotely via a network to Software platforms for analysis and presented graphically. In some cases the amount of data provided can obscure the meaningful information. Where many monitoring systems have historically fallen short is providing timely and actionable information in a concise manner. Today's technology has advanced so that information overload need no longer be an issue. The key is careful planning and understanding the goals each alarm will provide. Careful provisioning of alarming parameters is another key. Monitoring system manufacturers can be of great assistance and should help operators form clear goals for what information should be provided during an emergency and what actions should be taken for each alarm. When setting alarm thresholds the goal of the alarm should be clear so that the alarm thresholds produce alarms in time to take action but do not produce alarm storms. For example, voltage alarms could inform an operator of a discharge event and a more important alarm would inform the operator of impending battery “cut off” or failure an hour or two hours before drop out. One common mistake operators have made is to make alarm thresholds too tight or alarm on too many parameters causing real alarms, but alarms that do not really necessitate action.

Conclusions

Across our industry and across the nation, automation monitoring technology is being adopted as a labor-saving and reliability-boosting method for maintaining DC power and UPS battery plants. Automation has proven to provide a more accurate means of determining battery health & state of charge, and is changing the maintenance paradigm from a reactive process to a proactive one. Automated morning programs are far more effective for gathering consistent data and in dealing with events, even preventing catastrophic thermal runaway events or detecting an open-circuit cell. Instituting a proactive monitoring program has been shown to prevent outages and reduce costs, while improving the usefulness of data measurements. It won’t be long until every critical system in the world relies on automated systems for maintaining battery systems.

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