TO MONITOR OR NOT;
'TIS THE QUESTION

Curtis Ashton
Qwest Local Network
Power Maintenance Engineer, DMTS
Littleton, Colorado 80120

ABSTRACT

In a perfect world, every battery cell would be monitored continuously for every conceivable parameter mentioned in IEEE Standard 1491 (Guide to Battery Monitoring). Few failures would be observed because the user would be pre-warned of almost every potential failure so that they could take action before an event happened. However, the world is not perfect, and while reliability is very important, it must be weighed against cost. I work for a large RBOC (Regional Bell Operating Company), and have been involved in the decisions of that company as to whether to monitor batteries, what to monitor, and how to monitor it. This paper will give a synopsis of the thinking that led to those decisions in a world governed by budgets (a world in which we all live). Because of these economic constraints, the hazards and risks of whether to monitor, which parameters to monitor, and what equipment to use all have economic value.

As an example of what to expect from the rest of this paper; there are different risks associated with the type of batteries being used. For example, VRLA batteries are much more prone to thermal runaway than flooded lead-calcium or pure lead cells. However, in my company, less revenue rides on the back of our hundreds of thousands of VRLA strings than it does our tens of thousands of flooded battery strings because we primarily use wet (flooded) cells in our large COs (Central Offices). The risks would dictate that every VRLA should be more closely monitored; however, the economics dictate that flooded batteries will be more closely monitored.

TYPES OF SITES AND BATTERIES

Traditional telephone companies have essentially 5 types of sites with batteries. Permanently installed monitoring considerations and decisions vary by site type because the different types of sites support differing numbers of customers, generate different amounts of revenue, and use varying types of batteries.

The most well known sites are Central Offices. These sites, which support from hundreds (in rural areas) to hundreds of thousands (in metro areas) of customers, primarily use flooded lead-acid batteries due to their well-known long-life float characteristics. The batteries in these sites are usually kept in a controlled environment (air-conditioned and heated). These flooded batteries generally range in size from 1680 Amp-hrs to 4000 Amp-hrs per string, and each -48 VDC plant often has multiple strings of these 2 V cell/jars, although there are smaller and larger battery sizes used. Some large COs have multiple -48 VDC plants. The plant reserve time is determined by whether there is an auto-start auto-transfer engine-alternator on site. If so, battery reserve times vary from 3-4 hours depending on State regulations and company policies (this gives the phone company time to dispatch and fix the engine if it fails). Sites with only a plug for connection of a portable engine-alternator are typically engineered for 8 hours or more of battery reserve, depending on travel times, accessibility, etc. A subset of the COs are the microwave radio transport sites. Although very few (if any) end users are attached to these sites, they can often carry tens of thousands of long-distance calls at a time. These sites have both -48 and -24 VDC plants, and while most of the sites are equipped with flooded batteries, some of them have VRLAs due to space or transport restrictions.

The other large type of traditional telephone company site using batteries are the Data Centers. These sites are equipped primarily with multiple medium to large (30 kVA to multiple MVA) UPS systems using single or multiple string high-rate VRLA or flooded batteries, typically operating with DC bus voltages exceeding 500. The medium sized UPSs (30 – 300 kVA) primarily use 12 V VRLA monoblocks in cabinets. While the larger UPS primarily use large flooded batteries. The Data Centers also often have medium to large (like those found in a larger Customer Premises installation or a CO) -48 VDC plants to support equipment (typically fiber multiplexers, and related transport equipment) needing that voltage. Those plants can use VRLAs or large 2 V jar flooded cells. There are only a few dozen to a couple hundred Data Center installations in the typical traditional phone company. These sites are environmentally controlled.

The other major area where traditional phone companies have batteries is in their Outside Plant (OSP) electronics network. These batteries are primarily VRLA (although NiCd and LMP are beginning to make some inroads, especially in hot outdoor climates) due to the advantages of these types of batteries over their flooded counterparts in matters of space and handling. These batteries range in size from 2.5 Amp-hrs to about 1000 Amp-hrs per string in single or multi-string -48 VDC plants. Most of the smaller batteries are 12 V monoblocks, while most of the larger ones are 2 V cells. Although the investment dollars in OSP VRLAs are similar to the dollars spent on CO flooded batteries, there are far more VRLA batteries in service because there are about 20 times as many OSP electronics locations requiring battery backup as there are COs.

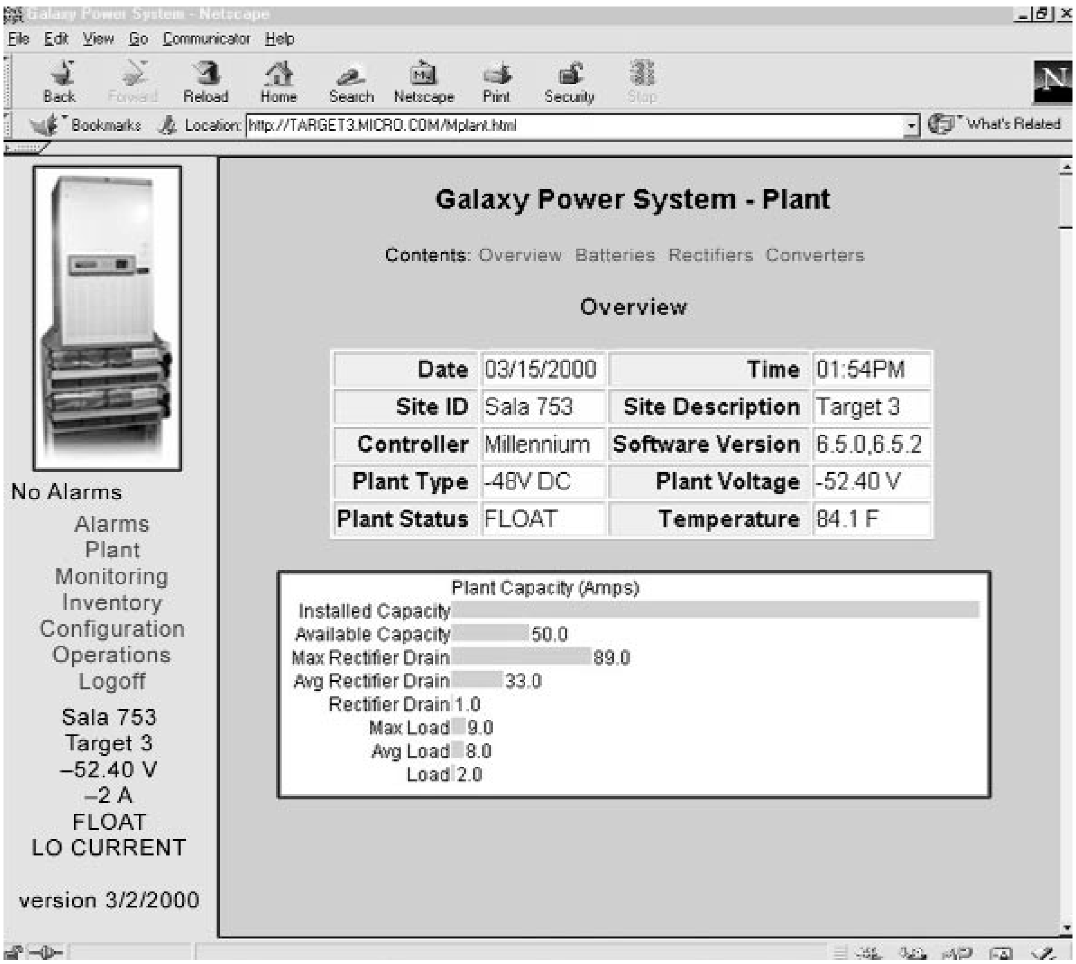
The OSP can be further subdivided into three subsets of site types. The majority of the sites requiring batteries are cabinets where there is little environmental control (the batteries will typically run within 5 C of the ambient outdoor temperature); although they also have battery heater pads that typically keep the batteries above 5 C (40 F). These cabinets might support a few high speed circuits (and some cabinets support a lot of them), but mostly support POTS (Plain Old Telephone Service) in increments from 24 to 2000 lines supported. The typical large telephone company (Regional Bell Operating Company — RBOC) will have tens of thousands of these cabinets. The batteries in these sites are mostly 12 V monoblocks from 12-180 Amp-hrs, arranged in multi-string -48 VDC plants.

The next largest concentration of battery installations for large telephone companies is in what are known as Customer Premises electronic equipment (CPE) installations. In these types of sites, a customer will generally want a lot of services (especially high speed data lines). The most economical way to do this for both the phone company and the customer is for the customer to give the phone company space in their building to install electronic equipment (such as fiber multiplexers). The equipment is primarily -48 VDC powered and owned by the phone company, while the space is owned by the customer. Sometimes, depending on the agreement with the customer, the customer supplies the -48 VDC power, and sometimes the customer supplies UPS and/or engine-alternator backed AC to the phone company's rectifiers and does not require the phone company to provide battery backup. In the majority of cases, the phone company supplies, owns, and maintains both the -48 VDC rectifier plant and the batteries that back it up. Like the cabinets, the majority of these batteries are small VRLA monoblocks from 4-170 Amp-hrs, although there are some larger installations using 2 and 4 V VRLA batteries in sizes typically from 250-2000 Amp-hrs. Generally, like the COs, the batteries are in an air-conditioned and heated (environmentally controlled) environment.

The final type of OSP application (of which there are a few thousand in the typical RBOC) are huts. They come in many different sizes, from as small as 40 square feet to as large as approximately 2,500 square feet. The great majority of them have 60-250 square feet of floor space. Almost all of them are heated and air-conditioned. Some are located fully above ground. Some are located fully below-ground (essentially a mostly sealed, environmentally controlled manhole, known as a Controlled Environmental Vault — CEV). And some are half buried (known by many different trademarked names, but generically referred to as a Walk-In Cabinet. All have -48 VDC plants (the oldest ones have distributed plants per bay, while the newer ones have a single common DC plant) with multiple strings of primarily VRLA monoblocks ranging in size from 25 Amp-hours to 500 Amp-hrs or more.

MONITORING EQUIPMENT CHOSEN

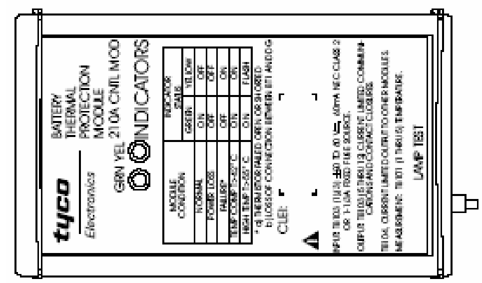
Most modern DC plants have microprocessor-based controllers. Many of the DC plant manufacturers offer monitoring products (either as an adjunct that talks to their controller, or as an integral part of the controller) for their larger plants. Some of the RBOCs, take advantage of these products to monitor the power plant (rectifiers and distribution), batteries, standby engine-alternator(s), DC-DC converters, inverters, UPS, residual ring plants, etc. These monitors typically monitor voltage (some monitor either AC or DC voltages, but most monitor only DC voltages) including binary contacts, and can monitor temperatures, currents, etc. through transducers. In a large site, hundreds of points may be monitored. The information is then transmitted to an alarm center (or viewed by Engineering or others with a need-to-know) as Telcordia TL1 messages, SNMP traps, html web pages, etc. over an IP or X.25 packet link (a sample html screenshot is shown below).



Other companies also offer stand-alone monitoring products, but they do not integrate as easily with the power plant controller. Qwest has used multiple monitoring products from multiple manufacturers in the past, but now primarily uses the Tyco Galaxy, the Emerson DGU and LMS1000, and the Multitel Mirador product for their large CO and Data Center DC plants. Pictures of some of the products are shown below (not to scale — they typically mount in a 23 or 19" mounting rack). They integrate into the main power plant controller bay.



In OSP sites, the power plant controllers generally don't have as many monitoring abilities (although there are exceptions, like the Lorain SMART® unit), plus the IP or X.25 transport capability is often not there. Most power alarms are transmitted in the fiber multiplexer (mux) or T1 overhead bitstream as simple contact closures. However, OSP sites have the more temperamental VRLA batteries, which are particularly sensitive to thermal runaway. Most of the power plant controllers are equipped with temperature sensing for the purposes of temperature compensation of the float voltage. Simple contact closure devices (they close at a certain temperature) from Thermodisk and Lorain (part of Emerson) have been used by Qwest. More sophisticated devices from Tyco's predecessor (Lucent in the power side of the business) have been used to do things like sense the differential temperature between ambient and the batteries (a better predictor of thermal runaway than absolute battery temperature). Multitel makes a pretty accurate float current monitor which can sense thermal runaway and VRLA end-of-life; however Qwest has not deployed this. There are dozens more manufacturers and devices used in the industry to monitor VRLA batteries. Example pictures of a few devices are shown below:

WHICH PARAMETERS TO MONITOR

There are so many potential things that can be useful to monitor on a battery with a permanently installed monitor, but not all of them have equal value, and the application and finances help prioritize the list. IEEE 1491 is the new Guide for Stationary Battery Monitoring, and lists the following potential parameters to monitor (along with Qwest's view of them):

- Float Voltage — easy to monitor and useful
- Equalizing Voltage — rarely used by traditional phone companies, and almost never used on VRLA cells
- Recharge Voltage — see the comments above on float and equalize voltages
- Open Circuit Voltage — impossible to monitor in our hot parallel float configuration
- Discharge Voltage — easy to monitor and useful when compared with time, temperature, and manufacturer discharge curves to determine battery capacity
- Individual Cell/Monoblock Voltages — can monitor, and has some use; the cost in monitoring every cell for every application may be prohibitive though
- Partial string or Midpoint Voltages — can monitor, and may have use in certain applications; cost considerations would typically limit it to midpoint measurements only
- String Current — fairly easy to measure discharge and recharge currents (which have some use), while float current is harder to measure (only 1 known manufacturer) but much more useful
- Ripple Voltage and Current — monitorable with specialized equipment, and useful on UPS systems, but not for typical telecom DC plants because the ripple coming from the rectifiers is extremely low
- Battery temperatures — fairly easy to monitor with transducers, and useful
- Ambient temperature — not as useful as battery temperature unless the difference between them is calculated
- Cycles — most useful for UPS or cycling applications (like photovoltaic installations), but not very useful for typical telecom applications because our batteries are not typically subjected to frequent and/or deep cycling, so they rarely die from cycling

- Ohmic (Impedance/Conductance/Resistance) Measurements — can be very useful, but hasn't been employed in permanently installed monitoring systems by most large RBOCs
- Specific Gravity — of little value for the lead-calcium or pure-lead cells most often used in telecom applications
- Connection Resistance — is of more importance in high-rate and long series connected strings (UPS applications)
- Ground Fault Detection — is typically more important in ungrounded applications (electric utilities) and long series strings (UPS)

Monitoring a battery plant more extensively in a CO (where there is a lot of revenue riding on the batteries, the batteries are expensive, and communications with the monitor is relatively easy) makes a lot of sense. However, these batteries are pretty reliable, so too much monitoring does not make sense. Typically Qwest permanently monitors the following parameters on flooded CO batteries:

- Plant Voltage — at all times (float, discharge, recharge)
- all String Currents — at the charge/discharge level; shunts aren't sensitive enough for float
- Room Temperature
- at least one Cell Temperature in the plant
- at least one Pilot Cell Voltage in the plant — along with plant voltage, and cell and room temperature data, this can be used for warranty purposes
- Midpoint Voltages — optional
- Battery Disconnect breakers — where used (only if required by an AHJ)

In Qwest Data Centers, the DC plants are monitored similarly to the CO plants (whether the batteries are flooded or VRLA). The UPS in COs and Data Centers are monitored only if the monitor is an integral part of the UPS. This is partly because a different part of the company (that is not as well-educated about batteries) is responsible for these systems, and partly because Qwest simply doesn't have a lot of UPS, so not a lot of capital expense attention has been paid to them (although we do have quarterly maintenance contracts on them in order to ensure reliability to some extent).

In Customer Prems, there is a lot of revenue riding on the batteries, and because they are mostly VRLAs, they are not as reliable as flooded batteries; however, alarms and communication are limited since the phone company doesn't own the location. Essentially, all that is monitored are binary alarms. Qwest usually permanently monitors the following at these locations:

- High Voltage
- Battery on Discharge
- Battery High Temperature
- slope Temperature Compensation — automatic; not alarmed
- Battery Disconnect breakers

Because huts are owned by the phone company, communications capabilities are slightly better (but not nearly as good as the CO), so in addition to what is monitored in a Customer Prem, Qwest typically monitors the following extra point:

- Differential Temperature — the difference between ambient room and battery temperature in order to predict thermal runaway

As noted earlier, the largest number of batteries are in outdoor cabinets. Also, because the batteries are primarily VRLA and the environment is uncontrolled, these batteries are the most susceptible to problems. From a reliability perspective, these batteries deserve the most monitoring. However, the quantity of sites, the generally low revenue produced by these sites, and the lack of sophisticated communications links all drive us to actually monitor fewer points on these batteries. Typically, Qwest monitors only the following battery-related items at these types of sites:

- High Voltage
- Battery on Discharge
- slope Temperature Compensation — automatic; not alarmed

IS IT WORTH IT? OUR EXPERIENCE

Qwest first began monitoring CO Batteries in the late ‘80s. We began by monitoring a lot of points. In the mid ‘90s we changed our philosophy due to experience. We didn’t ever receive a single midpoint voltage alarm on flooded batteries (VRLAs are a different story), and we were monitoring 2 temperatures per string in sites with controlled environments and pure lead or lead-calcium flooded batteries not susceptible to thermal runaway. We also monitored 1-2 pilot cell voltages per string; once again on batteries with historically high reliability. In short, for flooded batteries in controlled environments (where there are personnel visiting fairly frequently anyways), we decided that we could save money and not really sacrifice reliability by monitoring fewer (but key) points.

In the mid ‘90s Qwest and other RBOCs had several hazardous thermal runaway incidents in Customer Prems, huts, and cabinets. To protect ourselves, we retrofitted a lot of plants with full-fledged stand-alone monitors and began building new plants that way for huts and Prems. We even embarked on a project to begin retrofitting outdoor cabinets with battery monitors. Our experience taught us that it was very difficult to get inexperienced OSP installers to inexpensively make the connections correctly and program the monitors correctly. Probably only 10% of the nearly 1000 monitors we installed in the OSP ever worked completely properly. Many would argue that if we’d hire the right installers we could make it work. While that is true, we eventually determined that because of the smaller amounts of revenue generated by OSP sites, it was wiser to spend less money on monitoring but to monitor important things (like battery temperature). Also, from an alarm center perspective, our OSP sites don’t receive the same attention as a CO site, so by limiting the information received by the Alarm Center to the most important events, those events wouldn’t get lost in a slew of too much data.

Where we have begun to install alternative “smart” battery technologies, like the Lithium Metal Polymer (LMP) and various Li-ion technologies, these batteries are capable of providing lots of monitoring information. Because most of our installations of these batteries have been in the OSP, where we have limited communications capabilities, we’ve limited the alarms out of these to binary major and minor battery alarms. This is still an incredible improvement over VRLAs. I now have a battery that has its own built-in monitor to tell me when it is going bad. This is not done everywhere since these Lithium technologies have a much higher first cost than lead-acid technology. For us there has to be an economic payback to installing the Lithium-based batteries, or an environmental reason (space, weight, or non-gassing).

One area we have not explored that might provide more value is to permanently install ohmic monitors. Presently we use portable ohmic monitors to take measurements on periodic maintenance routines. As mentioned previously in the paper, we also might explore use of the float current monitor.

SUMMARY

Permanently installed monitors can provide a lot of useful information about batteries. However, the more that is monitored, the more the overall cost of the installation. What to monitor is a question that must be weighed against the economic realities of the given plant into which it is going to be installed. If the monitor costs more than the annual revenue of the site, it’s a sure bet that there is no economic payback in installing one. Whether the alarms and data generated by the monitor will be watched and/or analyzed by anyone also comes into play. The points/parameters to monitor can be prioritized (and might vary by the application and battery type used).

In Qwest, it is easy to monitor large COs and data centers, but generally reliable flooded batteries don’t need much permanent monitoring. VRLA batteries in the OSP world need much more monitoring to be reliable, but it does not make economic sense to monitor a lot of points at most of these locations. Only the most important points (such as battery temperature) are typically monitored.