# Midpoint Conductance Monitoring Technology In Stationary Battery Applications

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**Abstract:**

This paper will discuss issues important to any manager responsible for maintenance of network power systems. First we will show the ability to identify deteriorating batteries in Outside Plant cabinets using midpoint conductance monitoring technique. Data obtained using a Midpoint Conductance Transducer (MCT-148) was taken from common 48-volt telecommunications installations with various battery types as examples. Second, we will show it is possible to communicate the observed battery condition through common alarm system for remote status reporting. This strategic information can be used to help prioritize battery maintenance needs and to direct repair activity through the responsible NOC or NMA center.

**Introduction:**

Maintaining sufficient battery power reliability in today's distributed telecommunications networks is an important business issue. This conference is convened for the express purpose of giving the battery user a forum for obtaining relevant technical information. Hopefully, this is the kind of information you will find valuable in your respective work assignments.

In recent years significant data has been repeatedly published showing VRLA batteries are not meeting expected service life in Outside Plant environments. These premature capacity failures are spread across virtually every battery type commonly seen in field use today. To suggest all VRLA batteries fail prematurely however is simply not true. But the problem persists of determining which batteries are at the end of serviceable life and need replacement. Because of this experience, a considerable amount of time is being spent in industry workshops like this simply to vent user concerns. Discussion is important, and some new evidence suggests improvements in battery performance are being achieved, although no one is ready to suggest all the problems are behind us.

The early failure phenomenon of VRLA batteries even has it's own name, Premature Capacity Loss or PCL. With heightened awareness of the magnitude of the PCL problem, field test programs are being initiated and pressure placed on the battery manufacturers to offer a viable solution. In some cases, a field repair technique has even been attempted. The value of these field repairs may be unknown for a long time.

The core issue users face is simply this, in the event of an commercial power failure *"will the installed batteries perform equal their rated capacity?"* Despite the problems identified with VRLA batteries, the fact is we must rely on these battery types in our networks today for protection against the effects of a power failure. To date, there doesn't appear to be a technically superior battery available at a comparable cost to allow general replacement of all VRLA's, so what do you do? We ask all battery users this question: **"Do you have a technical problem or a management problem?"** Of course we believe the answer is - - - you have both! Let's examine the technical problems first.

**How to get started:**

Battery manufacturer's and equipment manufacturer's publish instructions on where, when, and how to install, operate, and maintain batteries and power systems. Some issues to consider for an installation include:

- Which cell design to use - Flooded, AGM or GEL?
- Which float voltage setting to use?
- Temperature compensated charging?
- Environmental enclosure for temperature stability?

Most of these issues are site specific and the responsible engineers must work within detailed guidelines to properly provision service. The environmental issues associated with battery operation are worthy of significant attention but fall outside the scope of this paper. Generally speaking, if batteries are not properly installed, charged, tested, and maintained it is unreasonable to expect to obtain the battery manufacturers' rated service life. With modem service demands and competitive pressure in the balance, full time passive battery monitoring may be the only practical way to *guarantee Network* service.

**Options for battery monitoring:**

Discussions with several users suggest a cost-effective way to monitoring the battery "State of Health" is what they want. The IEEE 1188 [1] standard suggests quarterly maintenance for VRLA cells, but many managers admit this is simply not being done. As a result, some companies have attempted to out-source power and battery maintenance. These programs can be a source of considerable anxiety as you hand over control of intimate network details to contractors. Thus there is pressure to find a battery monitor capable of reporting the presence of a PCL battery problem whenever and wherever they occur.

Because batteries tend to lose capacity gradually over time, it has been difficult to determine exactly when they need replacement without expensive site testing. The obvious question becomes "Is there an economical, accurate way to observe battery condition automatically and have it reported through our existing system?"

Today, a proliferation of battery monitoring options are available, some of which use a battery discharge algorithm to calculate available capacity. Discharge test algorithms usually use the site electrical load to exercise the battery and datalog the voltage change for the duration of the artificial outage. The voltage drop during this artificial outage can be used to project what the voltage slope will look like during an 8 hour discharge. This test technique can tend to be battery specific and the more information you have about each specific battery type, the more accurate the algorithms become. Battery temperature variations can also have an impact on the accuracy of this particular test technique. Despite these issues, discharge algorithms can work because they will give an indication of what battery capacity was when the discharge test was run.

Midpoint Voltage monitoring is another technique that has been around for a few years. This technique should be capable of identifying certain catastrophic battery conditions after they have happened. Midpoint Voltage deviations are not well documented in terms of their independent capability to predict battery failures, but are more likely to put a time stamp on when the problem has already happened. Some data interpretation is necessary for each of these techniques to be fully useful in a network setting.

### Conductance monitoring for battery management:

Conductance technology has gained widespread acceptance in standards organizations and with battery test equipment users worldwide. Ohmic battery testing in general and Conductance technology in particular has been identified as an effective way to passively assess a battery string "State of Health". When properly applied, this technology is capable of helping "reasonably predict" impending battery failures. This is especially important due to the maintenance limits of the "sealed" VRLA battery design. This paper focuses exclusively on the use of Midpoint Conductance measurement technology for monitoring stationary VRLA batteries.

Some of today's biggest challenges in effective Network management are data analysis from complex systems and alarm reporting from equipment nodes in this system, it can be overwhelming. Responding only to events that require action can save technicians time and save money for your organization.

Many component failures can be routinely detected and reported. Loss of commercial power, rectifier fail and circuit card failures are examples of events easily detected as *yes* or *no* problems. Up until now, battery failures have been much more difficult to accurately forecast. Exact battery capacity calculations require a full capacity test to guarantee complete accuracy, and few companies seem ready or willing to commit the time or staff to do that testing on a wide scale. With a Midpoint Conductance Transducer (Monitron® MCT-148) connected into your system, you have a new way to remotely find and report any network element with a PCL or other battery problem. By observing either the amount of change or a shift in the conductance balance relationship of cells 1 – 12 compared to cells 13 – 24, you have evidence of string capacity loss. Using patented technology, the MCT can be a valuable component in a comprehensive battery maintenance program. The Monitron® is tailored toward, but not limited to, Outside Plant locations with 24 or 48 volt battery string measuring between 250 to 3500 Mhos (Siemens). This includes most VRLA batteries with capacity ranging from 10 to 1000 Ampere-Hours.

### MCT Operation and Calculations:

Monitron conductance measurement and reporting is done continually and in real time. The key point is that no specific battery data or discharge activity is required to provide meaningful information. Battery Ampere-Hour rating and the site power load are irrelevant in this process provided they have been properly matched when they were constructed. The rule of thumb is "batteries with balanced conductance tend to perform well together". We believe the inherent efficiency of this design is obvious and an indication of how useful MPCD% monitoring technique can be.

For simplicity, let's create a theoretically perfect set of four 12V batteries assembled into a 48V string with a nominal conductance value of 1000 Mhos (Siemens) per battery. The deterioration model using 20% loss of conductance rule for capacity loss would say that when the battery reaches 800 Mhos (Siemens), it's state of health is suspect. If an MCT were installed on this perfect battery string and it's two analog outputs were adjusted precisely to 25mV at the time of installation, when the battery drops to 800 Mhos, the resulting mV output would be reduced to 20mV. This model simply says that the amount of change in the analog signals is in preportion with the loss of conductance for each half of the string. The user must specify how much change is acceptable for your respective networks. Here is how it works if you expand this concept:

**Table 1: Relative alarm values**

| Kmhos New | Time (?) | Cond. Loss | Alarm point |
|---|---|---|---|
| 1000 | 800 | -20% | 20.0mV |
| 1000 | 700 | -30% | 17.5mV |
| 1000 | 600 | -40% | 15.0mV |

**Application of MPCD% values:**

More published conductance information exists today than ever before. This includes base line reference or nominal conductance values from many battery manufacturers' to help with new MCT installations. These values can help identify which battery strings need immediate attention and which ones look healthy and therefore are logical candidates for monitoring.

Two sample battery strings are used to show the consistency common in new VRLA batteries. A third sample VRLA string was observed over several months to document what this battery's MPCD% looked like at the end of it's life. Each battery string was under float charge at the manufacturers recommended value of approximately 2.25 to 2.27 VPC. Table 2 shows the MPCD% calculated for cells 1-12 and 13-24 for each of the three sample string when first tested. The 12 cell conductance values are converted into 0-50mV output signals (Side #1=VA and Side #2=VB), one for each half of the battery string. Note: no special battery conditioning was performed prior to these observations.

**Table 2: Battery MPCD% Results**

| Battery String | Ampere-Hour Rating | MCT MPCD% |
|---|---|---|
| 1 | 40 | 2.17% |
| 2 | 60 | 0.4% |
| 3 | 250 | 7.1% |

Each MCT unit will react to the presence of a battery conductance unbalance problem by closing it's form A alarm contact which is normally open. This contact is activated when the **M**id**P**oint **C**onductance **D**ifference **%** (MPCD%) exceeds a user selected threshold. The threshold options available are 4, 8, 12, or 16% depending on the specific battery application. The % value is selected by changing dipswitch positions 7 and 8 on the MCT front panel. New batteries are usually closely matched in both performance and conductance as is shown for Strings 1 and 2 in Table 2. This same Table shows how older batteries will tend to have a greater % deviation as is seen in String 3 data. Our experience suggests a healthy battery string will be within the 8% MPCD range unless there are some unusual circumstance creating the balance shift. The user has the option to accept a greater % unbalance depending on site priority, strategic role of this site in your network and the actual State of Health of the battery being monitored.

**String 3 Data – Failure in progress:**

Listed on sheet 13-6 are two graphs that depict what an actual battery failure looked like to a Monitorn. We had the opportunity to observe this string in it's working environment and document the change taking place over an 8 Month period beginning in January, 1997. There are 9 data points listed in MPCD% graph because August is reported twice. One measurement is at the first of the month, the last reading is at the end of the month. This battery string was installed in an industrial park in the East Coast of the US supplying backup power to a fiber MUX. This site was equipped with a power plant monitor capable of reporting plant voltage and the site current load. We know that no alarm were ever received via normal channels to the company operating this site. We can't verify if the alarm thresholds were properly set, if the system was communicating properly or if the alarm was somehow disabled. What we did have however, was access to this site to independently observe this string as it hit it's end of life. Page 13-6 has the actual mV readings as reported for Sting 3 and the % difference between VA and VB respectively.

In terms of pinpointing the exact time these batteries were first in trouble, the 8% MPCD threshold was reached in May of 1997. This percent deviation is what was suggested earlier as an indication of potential failure. The MPCD% continued to increase through the summer months and the battery finally reached critical failure in August. One cell actually broke open some time in September, just prior to replacement. What is significant is the fact that the failure condition was detected early without the need for battery preconditioning or significant data analysis. Each operating company is still responsible for taking the appropriate corrective action for their equipment sites.

**Identifying battery capacity failures:**

The two mV channels of the MCT provide an analog representation of the measured conductance for the two halves of a 48-volt battery string. In order to identify the general decline of conductance over time, you must look at the MCT mV values over time. We recommend the user set the MCT analog outputs for VA and VB as close to the 25mV as is possible. Analog settings are adjusted by changing the positions of dipswitchs 1 through 6 on the unit front panel. The exact switch positions are set on site with the unit power cable cut to an even length and with all hardware properly installed and tightened. The current IEEE[1] model suggests a 20% loss of conductance is significant. But, most VRLA batteries seem to be rated very conservatively and this value may be a bit more aggressive than it needs to be. Let's say that -30% or even -40% loss of conductance is your replacement criterion, you simply observe the relative battery condition via the mV readings on the Monitron. This relationship information is shown in Table 1.

**Gross Battery Failure Detection Using MCT.**

One of the most catastrophic problems associated with any battery system failure is the loss of metallic conduction path or group bar corrosion. If this occurs the battery reserve is no longer available to provide energy. For VRLA technology the following causes for this problem have been reported:

1. Differences between strap and lug negative group bar alloy
2. Abnormal sulfation of the negative plate to strap when not submerged in sulfuric acid
3. Lack of cathodic protection
4. Highly Porous lead

We all know the battery manufacturers are anxious to resolve all PCL issues, but that won't solve your application problems today. Irrespective of which battery failure mechanisms may be impacting capacity, you can expect early failure in its discharge cycle if there are serious problems. It is possible that multiple failure mechanisms are at work simultaneously and it is merely academic which one is dominant. One-time measurements of conductance or quarterly measurements have been useful to examine the high resistance open circuits but may not detect all the changes that predicted the onset of strap failure. Therefore, we believe midpoint conductance monitoring will be able to identify the strap corrosion changes and give you a warning in advance of any catastrophic failure.

To verify this theory, we performed a simulated strap corrosion failure test by loosening one connection between two batteries in a sample string. We chose a strap on side A of a 48-volt battery string being monitoring with the MCT. We immediately observed the MCT fault (Red LED) indication showing a step change in the VA mV output. The normally open contact closed when the fault was detected and the string unbalanced fault condition was identified.

| Test Condition | MCT ($V_A$) Cells 1-12 | MCT ($V_B$) Cells 13-24 | MPCD % | MCT Alarm |
|---|---|---|---|---|
| Initial Conditions | 25.6mV | 26.7mV | 4.1% | No |
| Loose connection 1-12 side | 20.2mV | 26.7mV | 24.3% | Yes |
| Insert bad battery 1-12 side | 5.8mV | 26.7mV | 78.3% | Yes |

**Table 2: Gross Battery Failure Detection**

We performed one additional test by inserting a known bad battery with substantially lower conductance again into side A of this sample string and observed these results. Table 2 shows an even greater % change in the MPCD% on side VA mV because the magnitude of the fault was actually more serious. These simple experiments performed with the MCT demonstrate how continuously monitoring the battery string condition is possible and what to expect in the form of an alarm when significant Ohmic changes take place. These results are shown in Table 2. and can be easily duplicated in your network for further verification.

**What this means for you:**

We are not suggesting that all your battery problems will go away because you installed a battery monitor. But it is possible that you will never again have undiagnosed battery PCL problem with this managed maintenance approach. The introduction of MPCD% for battery monitoring can have a profound affect on how you prioritize your battery replacements, schedule maintenance visits and potentially how you battery purchasing contracts. Gone are the days when there were no tools available to overcome battery maintenance and monitoring issues. But you still need to incorporate this information into your existing alarm network to obtain the maximum potential benefits.

Because of the proliferation of alarm systems and architectures, it is very difficult to suggest the same simplicity in getting this information back into your NMA Centers. But make no mistake, the availability of this information is still valuable even if only preformed by technicians who are on site as part of their regular scheduled maintenance and installation activity. We have worked with a number of major alarm system companies and we may be able to offer some help in getting you started in the alarm automation process.

**Conclusions:**

1. Conductance monitoring combined with MPCD% functions will identify battery failures. This type of monitoring is capable of providing an alarm when a battery fault or a conductance unbalance occurs in a battery in real time which may be caused by any number of **PCL** failure mechanisms.

2. Continuous battery monitoring and trending of relative conductance along with MPCD% provides best overall information to access battery condition without an invasive discharge test.

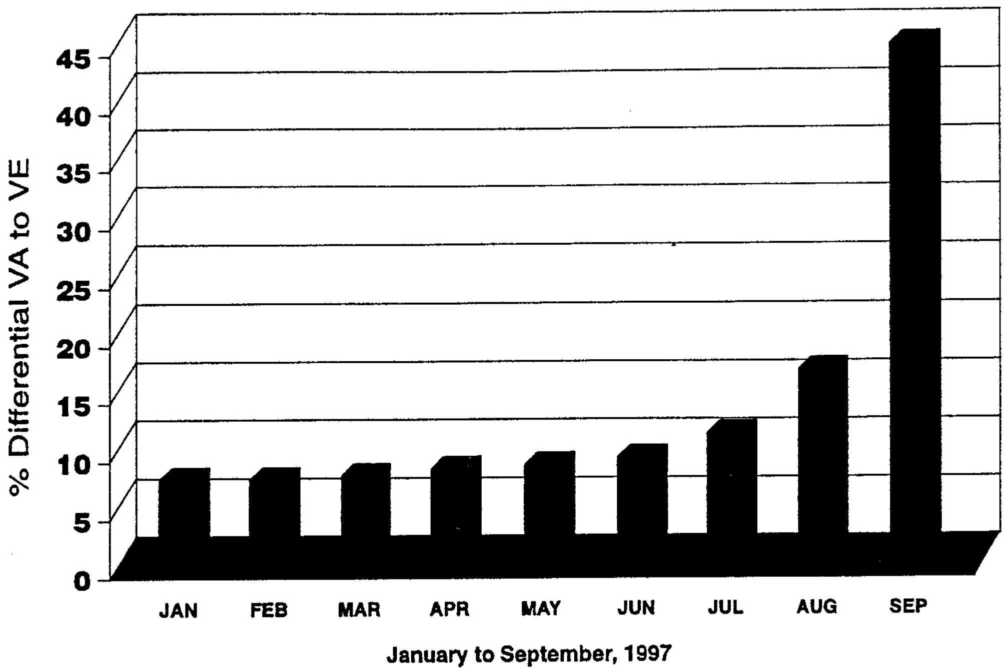
3. The MCT provides battery monitoring in real time and alarm capability using a proven technology. Additional diagnostics are possible using portable conductance testing equipment to isolate specific failed cells or monoblocks as required.

4. Monitron® MCT can interface to common alarm architectures with a simple contact closure or analog channels showing relative conductance, which can be used to indicate failures as they occur or for trending battery conditions.

**References:**

[1] IEEE 1888 (1996): "Recommended Practice for Maintenance, Testing and Replacement of Valve Regulated Lead Acid (VRLA) Batteries For Stationary Applications.

String #3 MPCD% Change In 8 Months




String # 3 MCT actual MCT mV Results