Battery Maintenance is (mostly) Worthless

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Abstract
Recommended practices for battery maintenance and testing on lead-acid batteries are well defined in IEEE 450[1] and IEEE 1188[2]. Unfortunately in many (most) cases, the IEEE recommended maintenance practices are not followed properly, the data is not being analyzed correctly or the technicians are not properly trained. Many times it is all of the above.

Consequently, given how many users perform/contract maintenance improperly and the reality that many users are satisfied with just "making it to the generator," the value of many battery maintenance activities is questionable.

Background
Recommended practices for battery maintenance and testing on lead-acid batteries are well defined in IEEE 450 and IEEE 1188. The IEEE Power & Energy Society (PES) Energy Storage and Stationary Battery Committee (ESSB), formerly the Stationary Battery Committee, have developed and maintains numerous stationary battery related IEEE standards. Considering the fact that lead acid technology is still the most used chemistry for stationary batteries, the most popular ESSB documents are IEEE 450 (Vented Lead-Acid Maintenance and Testing) and IEEE 1188 (VRLA Maintenance and Testing). While there are other chemistries, this paper will only focus on lead-acid.

For maximum reliability it will always be recommended to properly perform the IEEE recommended maintenance.

Both IEEE 450 and 1188 recommend monthly, quarterly and yearly maintenance intervals. Additionally, both documents recommend periodic performance testing. Tables 1, 2 and 3 provide a summary of these recommendations.

Table 1. IEEE 450 Maintenance Summary

Frequency	Recommended Maintenance
Monthly	Overall Float Voltage Visual Charger Output Electrolyte Levels Ambient Temperature and Ventilation Charge Current Unintentional Grounds
Quarterly	Cell Voltage Representative Cell Temperatures Representative Specific Gravity (specific cases)
Yearly	Cell Specific Gravity (specific cases) Detailed Visual Inspection Intercell Connection Resistances Rack Integrity checks

Table 2. IEEE 1188 Maintenance Summary

Frequency	Recommended Maintenance
Monthly	Overall Float Voltage Visual Charger Output Ambient Temperature and Ventilation Charge Current
Quarterly	Cell/Unit Voltage Cell/Unit Temperatures Cell/Unit Ohmic Values
Yearly	Intercell Connection Resistances AC Ripple Current and/or Voltage

Table 3. Performance Test Frequency Recommendations

Document	Performance Testing Frequency
450	Upon installation (or a factory test) and within the first two years and then periodically with intervals no greater than 25% of the expected service life.
1188	Upon installation and then periodically with intervals no greater than 25% of the expected service life or every two years, whichever is less.

For most users, the IEEE recommendations are not followed completely and in some cases are not followed at all. The main exception is the nuclear power industry where most, if not all of these recommendations are followed carefully.

For owners of battery systems, the challenges in ensuring reliability are multi-faceted. Reliability has to be built into design, product selection, installation, commissioning, maintenance and testing. This paper will only focus on maintenance and testing; however, if the other items are not performed properly, no amount of maintenance will offset the loss in reliability from problems in the other areas.

Battery maintenance, as defined by IEEE recommendations, is more about predicting when the battery will fail rather than preventing or delaying battery failure. There is not a great deal an owner can do to prevent a battery failure other than ensure that the environment (e.g. voltage, temperature, current) is within specification. Most of the activity recommended by IEEE is to predict when the battery is, or will be, failing or does not have the capacity to meet the required reserve time.

The first challenge for most owners, with respect to battery maintenance and testing, is to determine what maintenance and testing regimen is needed to ensure required reliability. Even if the owner knows their system's required reliability, (e.g. .9999), the allocation given to the batteries is usually unknown. If by some chance the owner does know the allocation given to the batteries, (e.g .99999), there are no IEEE guidelines, or any guidelines known by this author, that can equate a level of maintenance to a specific reliability. To further complicate the matter, even with ideal maintenance, battery reliability can be greatly affected by design, product selection, installation and commissioning.

The IEEE recommended maintenance practices were developed to maximize reliability of a stationary battery system "…without consideration of economics…". Monetary issues are obviously a key consideration and most owners will accept, or are accepting, a reduction of reliability for the sake of cost savings.

The main point for owners is to determine the acceptable level of battery reliability and the minimum associated cost they can incur with respect to battery maintenance.

Issues with how maintenance is typically implemented

There are two major pitfalls with most battery maintenance programs. One is incorrectly selecting the proper maintenance schedule and the other involves implementation.

Both pitfalls must be avoided to ensure success. For example, a good visual inspection could be sufficient to meet the owner's required reliability, but if the inspections are not carried out by knowledgeable, trained and qualified technicians, the cost of the program may be completely wasted.

Periodic performance testing is the most expensive battery maintenance activity and it can also be a logistical issue. Economics typically drive the decision to not include testing as part of the maintenance plan. Many times this decision is rationalized with the belief that battery health can be sufficiently assessed with lower cost techniques. The reality is that reliability is reduced, maybe significantly, if a testing regime is not included into the maintenance plan. However, this reduction in reliability may be acceptable depending on the needs of the owner.

For vented lead-acid batteries in clear containers, visual inspections can provide great insight into the state of battery health, if an experienced technician is conducting the inspection and documenting the results. Conversely, VRLA batteries, which are typically less reliable than vented cells, have less visual clues when determining battery health. However, VRLA systems tend to be smaller than the average vented battery system and have less value and so therefore the economic pressure to reduce maintenance costs is usually greater.

For anyone with extensive experience with lead-acid batteries, the ability to know that the battery has sufficient capacity to meet the design requirements is difficult, if not impossible, without conducting an IEEE performance test. However, many times it can be determined that a battery is about to fail catastrophically without a performance test.

Internal ohmic readings are typically what are used to assess the state of health in VRLA batteries, especially if performance testing is not being used. Many papers have been written over the years on ohmic measurements and there continues to be debates on the viability of this technique. There is general agreement on the diagnostic value of ohmic readings for VRLA cells but not with vented batteries. While some users have verbally reported value in utilizing ohmic readings for vented cells, very little data has been presented to substantiate these claims. Conversely, numerous papers have presented data in support of utilizing ohmic testing for VRLA batteries.

While this paper is not intended to be a comprehensive review of ohmic readings, the data does show that ohmic measurements do not perform well in determining a specific capacity, especially in the critical 80-100% range[3]. Additionally, there are many complications in the use of ohmic readings from the placement of the probe to the analysis of the readings[4]. The key issue is that while there is value in using ohmic readings to help predict cell failures, this technique will not ensure that the capacity meets the user's required reserve time. This concept is not necessarily an issue to many users. It is, however, a discrete reduction in the reliability/predictability of the battery system as compared to a maintenance program that includes IEEE performance testing.

Although a battery system is sized for a specific reserve time, (e.g. 4-8 hours for telecommunications, 1-3 hours for utility applications, 15 minutes for UPS), the vast majority of batteries are never subjected to an outage where the full reserve time is utilized. The reason that batteries are typically not fully utilized is a combination of a relatively reliable grid, oversizing, the actual load is less than the design (many times much less) and the presence of a generator. Another key point is that the vast majority of grid outages last a very short time.

In order to make any maintenance plan effective, it is absolutely critical that the technicians are fully trained in taking measurements and collecting and analyzing data properly. Adequate training is especially important for ohmic testing since it is not an exact science. Batteries are not resistors and ohmic testers interpret responses to inputs based on proprietary techniques and algorithms. There are no industry standards for ohmic technology. Users typically select devices based on company reputation and experience in the absence of standards. Additionally, the interpretation of ohmic readings is somewhat subjective and relies on the experience of the analyst. Therefore, the effectiveness of ohmic measurements can vary widely depending on the device and the skill of the technician performing the reading as well as the person analyzing the readings.

The burden is on the owner to ensure qualified personnel are designing and executing the maintenance plan. The problem is that there is no industry certification to help the owner select/train/qualify capable personnel to design/execute battery maintenance. The ESSB has laid the groundwork for this to occur by publishing guidelines and recommendations for personnel training and certification and program accreditation[5]. However, while individual organizations have developed training courses based on the IEEE standard, there is still no accreditation body to oversee and regulate the training.

Battery maintenance is complicated by the fact that many of the inspections and measurements are subject to interpretation. Table 4 identifies some of the subjectivity.

Table 4. Subjectivity of Battery Maintenance

Battery Maintenance Activity	***Subjectivity***
Visual Inspections	Visual inspections are inherently subjective.
Ohmic measurement	The readings are best trended. However, there is no universally accepted change in baseline to determine when the battery capacity is below the system design point. Values vary by battery type, manufacturer, meter, probe type, location of reading and temperature.
Connection resistances	Connection resistances should be compared to baseline values which are typically not available. Unique connections, (e.g. inter-tier cables), have to be analyzed separately and require engineering judgement in many cases.
Specific Gravity	Most specific gravity variation in stationary batteries is due to level differences, recent water addition and incomplete mixing. These variations are seldom signs of performance issues if other parameters are normal.
Float Voltage	While extreme voltages, especially low ones, are clear signs of issues, most voltage variation does not affect performance or life. Identifying the dividing line between critical and acceptable can vary with the model, manufacturer, age, specific gravity and the presence of replacement cells.

The subjectivity of battery maintenance, combined with the lack of technician qualification standards, should be a concern to any battery system owner.

Many service companies are very skilled in recording measurements and filing data. However, the value of the data is probably not worth the cost if the information is not analyzed properly. If an owner selects a subset of the IEEE recommended maintenance practices, low bids the maintenance contract and does not audit the process to ensure that the work is being executed properly, there is a fair chance that the battery maintenance is worthless. The mitigating factor is that the full reserve time of any battery is seldom utilized. Even very marginal battery maintenance plans can ensure a battery is at least operational for short outages or for a generator transfer.

However, there are organizations that perform battery maintenance correctly and effectively, even if all of the IEEE recommended practices are not being followed. These effective programs are usually where the owner is highly knowledgeable and can properly evaluate and audit the work.

It has been the experience of the author that many organizations are preforming what they believe is an effective battery maintenance program, but it is not. These ineffective programs are justified by the fact that their batteries have performed adequately when called upon. The reality is that stationary batteries are seldom required to provide the design reserve time. Although the maintenance program may be ineffective, it can be masked if there is excess battery capacity and low expectations.

Significant savings may be realized by scaling back battery maintenance programs that are not effective. This may be accomplished without reducing reliability. Alternatively, the savings may be in reducing battery reserve time to match the true expectations. However, if excess reserve time is not available, a robust battery maintenance regime must be put into place to ensure that the required reserve time is available when needed.

Case study

For many small, lower value sites, maintenance practices are minimized for a variety of reasons. While one of the main reasons is economics, other issues come into play as well such as lack of available expertise and complex logistics getting access to the site.

This case study involves a small telecommunications office with a single string of VRLA cells and a generator. In this particular case the batteries are sized for four hours. There is also a generator that backs up the building. For the aforementioned reasons, the battery maintenance plan is essentially limited to periodic ohmic measurements from a hand held meter. The ohmic readings are compared to the manufacturer provided baseline value and when the actual reading drops to an agreed upon (between the owner and the manufacturer) percentage of the baseline, the battery is slated for replacement.

In this case the designated technician dutifully completed the periodic ohmic measurements and cataloged the data. A picture of the records is shown in Figure 1.

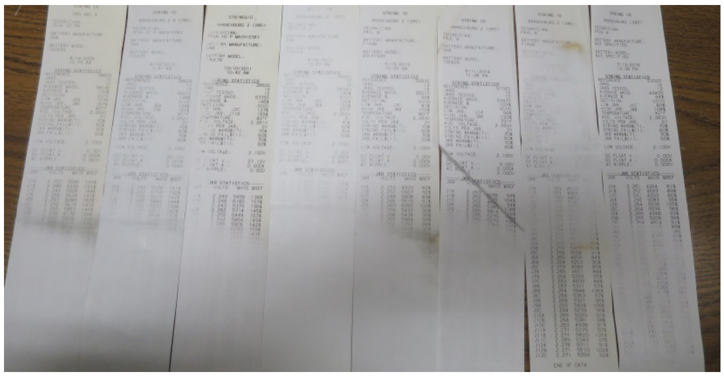

Figure 1. Battery Maintenance Records

The data show that the cell voltages were in specification and were very consistent (see Figure 2). The ohmic readings were well above the manufacturer's provided baseline value (see Figure 3). This particular ohmic meter reports the readings in Siemens which trend lower as the battery ages.

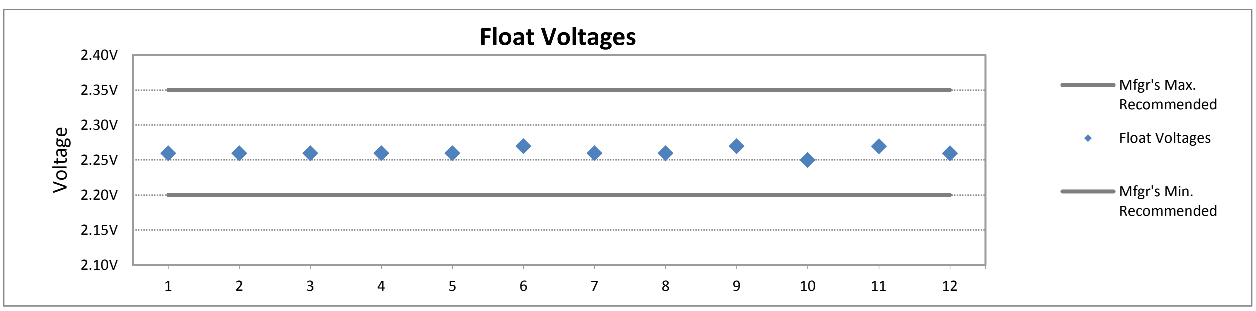

Figure 2. Float Voltages

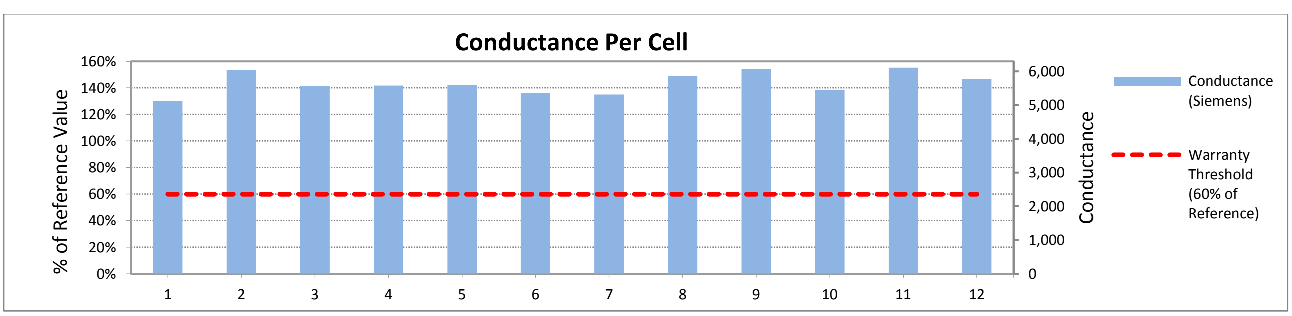

Figure 3. Ohmic Readings

There were also no visible clues that the battery may be failing.

Normally, a generator provides backup power to the entire building. When there is a commercial power failure, the generator automatically starts and transfers the power in less than 30 seconds.

Due to some building testing, the generator was taken off line and power was cut to the building. The battery failed soon after the power was cut.

An IEEE battery performance test was conducted on the battery after power was restored to the building and the battery was recharged. The results of this test are shown in Figure 4. The battery capacity was determined to be 6%. Over half of the cells were below 1.75 volts after 13 minutes of a three hour scheduled test.

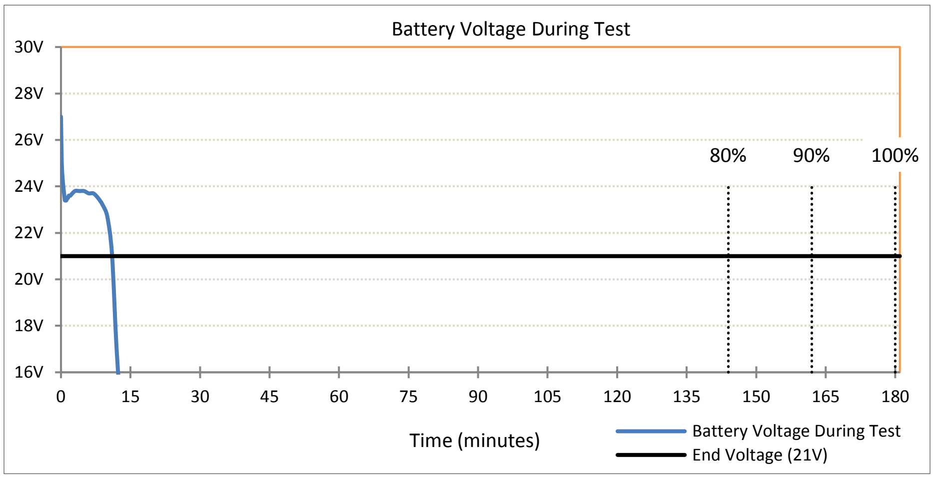

Figure 4. Battery Test Results

If the point of the battery maintenance was to ensure a four hour reserve time, it was worthless. Periodic performance testing would have been the only way in this case to determine that the battery was not meeting the design.

In this case study, the maintenance activity was inadequate to ensure the four hour reserve time. The adequacy of the maintenance activity cannot be determined if the goal was just to ensure enough reserve time to transfer to the generator. However, if the goal was only to transfer to the generator, a great deal of money was wasted buying an oversized battery. In either situation, there are opportunities for significant cost savings. While this is just one case, it is indicative of many situations throughout the stationary battery industry.

Summary

In a perfect world, every battery maintenance program would follow the IEEE recommendations. In addition, all battery maintenance activities would be performed by qualified technicians and the data would be analyzed by trained personnel. In this perfect world, battery maintenance is not worthless, it can be used to maximize reliability and be able to predict when the battery will not perform as intended.

However, in reality most owners are willing to trade reliability for reduced costs. The challenge becomes to determine the amount of lost reliability/predictability involved in this tradeoff and to ensure that the owner understands the reduction.

Any battery maintenance program is only as good as the technicians performing the inspections/measurements and the personnel analyzing the data. In many cases, the personnel are not properly trained which can significantly reduce the value of maintenance activities.

Many users may not realize that they have an inadequate maintenance plan because they have not experienced any significant system failures due to battery issues. The aforementioned case study prior to the failure is a good example. A lack of failures is not a good metric in determining if the maintenance program has any value. In the case study the battery was sized for several hours but the actual expectation was that the battery would support the transfer to the generator. While the battery maintenance activity appeared to be effective, it essentially had no value.

Overdesign/underutilization can compensate for inadequate maintenance. While the end result may be acceptable because there are few system failures due to batteries, the fact is that there may be significant savings in ‘right sizing’ the batteries and implementing a maintenance plan that will actually ensure the full reserve time of the battery.

The conclusion is that there is a lot of opportunity in the stationary battery industry for savings if the maintenance program is critically reviewed in conjunction with the practical sizing of the system. In some cases, at least, the existing maintenance program as implemented is not providing much value and could be scaled back significantly with little, or any, loss of reliability. In other cases, significant savings could be realized by reducing the reserve time and implementing an effective battery maintenance plan.

References

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