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Ohmic Measurements as a Maintenance Tool for Lead Acid Stationary Cells

Executive Summary

The use of Ohmic measurements on lead acid stationary cells has been gaining popularity and EnerSys continues to actively investigate the commercially available test equipment and the resulting data when our products are tested in accordance with the manufactures recommendations. In the end, when these Ohmic measures are trended over time, insight can be provided into the expected life of a cell. It must be noted however these values, regardless of the source, must account for measurement variations that can occur during manual readings and that use of absolute readings can sometimes lead to false conclusions.

The use and application of Ohmic measures is well documented throughout the industry including publications from IEEE, battery manufacturers and even the equipment manufacturers themselves. Collectively, these organizations recommend trending of the data over the lifetime of the cells. More and more, select users are requesting reference values that are used as ultimate min/max limit for their cells and to base warranty replacements on.

Based on the market experience and expectations of lead acid batteries, EnerSys can and will support specific customer requirements based on this technology. These programs are developed individually with very specific focus on customers, products, equipment and applications. In some cases, these programs are used as a guideline for cell replacement. In all cases though, normal preventive maintenance practices such as those listed in EnerSys published instructions and IEEE standards cannot be ignored.

Background

Until about 20 years ago, virtually all lead acid stationary cells were supplied in containers made of clear materials and were of the flooded electrolyte design. The battery purchaser and his maintenance technicians had several excellent tools available to measure, monitor and trend the "health" of individual cells or battery units with these flooded designs; i.e., electrolyte specific gravity (S.G.) readings, electrolyte temperature readings, cell float voltage readings, visual observation of the cell element stack and the sediment space through the clear jar.

With the increasing use of sealed VRLA (valve regulated lead acid) cells in the early and mid 1980's, maintenance technicians lost the use of most of the above tools since these VRLA designs utilized opaque containers and "starved" electrolyte systems that were immobilized in a gel or porous separator. The only tools they had left were voltage readings and periodic discharge tests. A search was soon on for other health monitoring tools for VRLA products, particularly since some of the early designs suffered from short life, high infant mortality and sudden (without warning) failures.

Various instrument manufacturing companies took note of this dilemma and started to design/manufacture/market test equipment to determine internal Ohmic measurements of cells such as impedance, conductance, and internal resistance that could be used to assess the health of VRLA cells/strings.

It is also important to note that EnerSys and our predecessor companies have extensive experience with these Ohmic measurement devices going back to the early 1990's.

Definitions

The information in this section is taken from and paraphrases the wording in IEEE Standard 1187-1996.

Ohmic measurements provide information about cell or battery unit circuit continuity.

The internal Ohmic measurement of a cell consists of a number of factors, including, but not limited to, the physical connection resistances, the ionic conductivity of the electrolyte, and the activity of electrochemical processes occurring at the plate surfaces. With multicell units, there are additional contributions due to intercell connections. The resultant lumped measurement can be quantified using techniques such as the following:

a) Impedance measurements can be performed by passing a current of known frequency and amplitude through the battery and measuring the resultant ac voltage drop across each cell/unit. The ac voltage measurement is taken between the positive and negative terminal posts of individual cells or the smallest group of cells possible. Compute the resultant impedance using Ohm's law, which is normally done automatically by the meter.
b) Conductance measurements can be performed by applying a voltage of known frequency and amplitude across a cell/unit and observing the ac current that flows in response to it. The conductance is the ratio of the ac current component that is in phase with the ac voltage, to the amplitude of the ac voltage producing it.
c) Resistance measurements can be performed by applying a load across the cell/unit and measuring the step change in voltage and current. The Ohmic value is calculated by dividing the change in voltage by the change in current.

Equipment Availability and Standardization

In the market today, the battery maintenance technician has available, literally, dozens of Ohmic measurement equipment choices from almost as many different manufacturers. This is actually a "negative" rather than a "positive" to the industry. Unfortunately, as the market grew and competition took hold, there were no standards developed or used to mandate the test signal that the equipment imposed on the battery. Some manufacturers use high frequency, some low frequency and some multi-frequency. Because of this, not only are impedance vs. conductance readings of the same cells not compatible to each other; usually, conductance vs. conductance or impedance vs. impedance readings from different equipment manufacturers are not compatible. Internal resistance meters, which use very short duration imposed discharge data, are also not compatible with the imposed voltage/current techniques of impedance/conductance. Essentially, from a standpoint of standardization of data produced, there is chaos in the industry.

Use of Internal Ohmic Measurements

What Ohmic resistance readings cannot do is replace the time honored discharge test to determine % capacity or ampere-hours capacity. Much work has been done and many papers have been written on this subject, but there is no conclusive proof of the concept and it is not an accepted industry technique for capacity determination.

The correct way to use Ohmic readings is as a trending tool over time to detect potentially weak or troublesome cells in a VRLA battery string in float in service. When the string is first installed and stabilized, a set of "initial" Ohmic reading should be taken. Since at this time there may still be some significant variations cell to cell in state of charge, separator acid content, recombination efficiency, gel stability, etc. it is not unusual for these initial readings to be about ± 50% around average. If there were some cells that exceed this, it would be judicious to equalize charge the string and possibly do a capacity test.

After the string has been in service for about 6 months, the previous mentioned variations tend to normalize. At this point another set of Ohmic readings should be taken and considered the "baseline" readings. At this point, the cells should be within about ± 30% of average string readings.

These individual cell "baseline" readings will serve as a reference for trending purposes for comparison to readings taken later in life. On a quarterly basis, Ohmic readings should be taken, recorded and compared to the baseline readings. If a cell or battery Ohmic reading should vary more than 50% from the baseline value, the cell/battery should be further evaluated to determine the cause. A performance or capacity test should be part of this evaluation.

Application Effectiveness

As stated previously, Ohmic readings cannot and should not be used to predict actual absolute capacity values in cells or batteries.

Ohmic readings where used in a trending mode can be an effective tool to locate troublesome cells that could be deteriorating in performance due to conditions such as electrolyte S.G. change, electrolyte dry out, case/cover/seal/valve leaks, gel deterioration, separator deterioration/shorting, edge shorting, or grid corrosion. These are the type of failure modes that, over time, would cause a gradual change in Ohmic readings that could exceed some "trigger point" such as the 50% change value mentioned above.

There is one type of failure mode that Ohmic readings are generally not effective in diagnosing. A condition that would provide "normal" trending values over time but then rapidly or instantly fail would not be detected by the above-outlined trending techniques. There is one known failure mode in VRLA cells that would fall into this category and that is negative side corrosion (NSC).

Much has been written in the literature about NSC and it's causes, methods of prevention, etc. and I will not repeat that in detail here. A very brief summary of the subject is that in VRLA cells, under certain conditions of localized environment, aggressive corrosive deterioration of the negative pole/post and/or strap can proceed very rapidly. Normally, there is sufficient metal thickness and cross-section in the strap and/or post so that acceptable Ohmic readings are seen as this rapid corrosion progresses almost up until the part corrodes through and the cell fails “open”. This “open” failure can result in a serious situation where the electrical integrity of the whole string is instantly gone and the customer loses his battery support. Ohmic readings, in a normal maintenance program, are taken at monthly or longer intervals; and they are generally not effective in predicting NSC failure.

Factory Ohmic Readings Requested by Customers

It is becoming more common for customers to request or even require that Ohmic readings be supplied with VRLA cell shipments. This data, when supplied, can often be troublesome, inaccurate and at times misleading to the customer.

There are two potential “uses” of this factory taken Ohmic data.

(1) Identification of Suspect or Weak Cells/Units – This is a legitimate and useful technique and can help the battery manufacturer weed out problem cells. However, if the battery supplier includes a discharge test as part of his manufacturing process, as is often the case, then these Ohmic readings are generally not needed since the discharge test will identify weak cells. Where discharge tests are not part of the manufacturing process it is recommended that Ohmic readings be used as a final screening before shipment. These readings can be taken while the cells are on open circuit and in general, cells that are ±50% out of the string or lot average should be considered in need of further evaluation such as a capacity test.

(2) Baseline Readings for Later Customer Use – this use of factory supplied Ohmic data is highly questionable and probably of little use to the customer. In order for the data to be of any use later it must be taken while the cells are in a float-stabilized condition. Since most manufacturers do not float VRLA cells for a long enough duration to significantly stabilize the cells as part of the normal process there is little added value to “out of the box” performance.

If the factory readings are taken with an impedance meter from Manufacturer ABC and the customer’s maintenance technicians use impedance meters from Manufacturer XYZ then the data is probably useless to the customer. With dozens of meter systems available in the industry it is not practical for the manufacturer to take readings with all possible available systems. The potential mix of impedance readings at the factory versus conductance or internal resistance readings by the customer makes this even more troublesome.

Even in the few instances where the factory readings are taken with the same equipment used by the customer; the factory data is not generally valid as “baseline” for trending purposes due to changes that occur in the cells during shipment, handling, storage and the first few months of float service. See discussion in “Use of Ohmic Readings” section above.

Ohmic Readings for Flooded Cells

Most of the discussion in all of the above sections, which is directed toward VRLA cells, would apply to flooded stationary cells also. As detailed in the “Background” section there are many tools available to the maintenance technician to assess the state of health of a flooded cell without the use or need for Ohmic measurements. They certainly can be used in the same way as they are for VRLA cells and the limitations and qualifications discussed in the previous paragraph would apply. The only exception is the discussion regarding negative side corrosion, which does not occur in flooded cells as long as electrolyte levels are maintained above the plate tops.

Recommendations/Conclusions

- Ohmic measurements are not a substitute for capacity testing and should not be used to predict absolute capacity values.

- Ohmic measurements can be used as a trending tool over time in field service to identify weak cells that may require further evaluation.

- Ohmic measurements taken at the manufacturing factory can be misleading and at times not useful as baseline data for trending studies in field service.

- Battery suppliers that do not use capacity tests as part of their manufacturing process to identify variation should consider the use of Ohmic readings.

- Other tools available for flooded cells such as electrolyte specific gravity, level and temperature; as well as visual observations of sediment volume and color are the primary items to be looked at. Ohmic readings for flooded cells can be somewhat useful, however should be considered more of a secondary tool.

- Ohmic readings should always be acquired utilizing the same testing equipment, to assure accurate / consistent results. Changing test equipment can nullify previous data for trending purposes, and in many cases new baseline values must be established to restore future trend analysis.

- Since Ohmic readings depend greatly on the surface condition of the connection and the location of the connection of the instrument, care must be taken for data trending to be effective.

- With the above said, EnerSys can and will support specific customer requirements based on these measures and based on specific details agreed upon by both companies.