Battery Council International

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Recommended BCI Procedure for

Ohmic Measurements as a Maintenance Tool for Lead Acid Stationary Cells

Scope

This information concerns the use of ohmic measurements as a tool for assessing the health of lead acid battery cells and monobloc batteries in stationary applications.

Executive Summary

The use and application of ohmic measurement 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. It is becoming increasingly common, however, for end users to request reference and min/max values that are to be used as the absolute basis for warranty replacement.

Battery manufacturers, equipment makers, and end users all have had active research programs in the use of ohmic measurement techniques, and there is general agreement that when used properly, insight can be provided into the expected life of lead acid battery cells and the possible presence of low capacity product. This is especially true for measurement techniques that track or trend behavior of batteries or cells over the product life. It must be noted, however, that analysis of these measurements, regardless of the source or instrument used, must account for measurement variations that can occur during manual readings and that the use of absolute readings (comparison to a standard value, or use of rigid minimum/maximum values) can lead to false conclusions regarding battery capacity and quality.

BCI recommends that any procedures that use ohmic data as a criteria for cell or battery replacement be co-developed by the battery manufacturer, equipment manufacturer and end user for the specific application. In all cases these procedures should take into account recommended normal preventive maintenance practices for the battery systems as well as recommended standards such as IEEE.

Background

Until about 20 years ago, virtually all lead acid stationary cells were flooded batteries, supplied in containers made of clear materials. Battery users and 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 traditional maintenance tools. VRLA designs use opaque containers, and all electrolyte is immobilized in a gel or porous separator material. The only tools left were voltage readings and periodic discharge tests. Full discharge tests, while serving as the definition of product quality, are intrusive (the system usually had to be taken off line) and expensive. 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.

Definitions (Adapted from 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

There are dozens of different equipment designs available today. This wide variety, combined with the lack of universally accepted testing standards, makes equipment selection complicated for the end user, and compliance difficult for the battery manufacturers. In addition to the three general ohmic methods described above, there are other variables involved in measurements, including:

- Signal strength (Conductance/Impedance)
- Signal frequency (Conductance/Impedance)
- Lead lengths
- Probe design
- Discharge rate (resistance meters)
- Discharge length (resistance meters)

Due to these variations, not only are readings taken by different measurement methods incompatible, but readings taken by different pieces of the same model of equipment are usually incompatible. Essentially, from a standpoint of standardization of data produced, there is chaos in the industry.

Use of Internal Ohmic Measurements

Research on ohmic testing has shown changes in readings with some changes in cell behavior. This is especially true of failure modes such as dry out and compression loss, especially when these mechanisms are fully developed.

While readings do show behavior changes with time in some types of VRLA products, what has not been proved is a good correlation between ohmic readings and capacity. ***Ohmic resistance readings cannot replace capacity testing in new or aged products to determine percent capacity or ampere-hours capacity***. This finding has been confirmed in numerous research papers on many different types of VRLA and flooded product.

Repeated testing has shown that the most effective use of ohmic readings is as a trending tool over time to detect potentially weak cells in a VRLA battery string. When the string is first installed and stabilized, a set of initial 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 very unusual readings are found, equalization, and if necessary, capacity testing can be performed to investigate any performance problems.

Extended float operation tends to normalize initial cell variability. After the string has been in service for about 6 months, 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, along with the other information required by the battery manufacturer. 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 cells that could be deteriorating in performance due to conditions such as electrolyte specific gravity changes, 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 may be detected using an effective trending program.

Ohmic readings are generally ***not effective*** in diagnosing internal corrosion problems that cause deterioration of metallic connections in the cells or batteries. Due to the nature of metallic connections, a very small contact area in a cell would still have very low impedance, while being incapable of carrying full discharge current. Positive and negative strap corrosion, lug corrosion, terminal post corrosion, and other similar problems are typical of these phenomena. A user trending ohmic data would only see a gradual increase in impedance, followed by a rapid rise as the last of the metallic connection is eroded away. The failure of series connected internal components results in an "open" cell or battery, which cannot discharge any appreciable current.

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 connector corrosion failures. Connector corrosion can be prevented by appropriate battery design and careful process control. Battery users must take this into consideration when reviewing and selecting the product used in their systems.

Factory Ohmic Readings Requested by Customers

It is becoming more common for customers to request or 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 Low Capacity Units – This is a legitimate and useful technique and can help the battery manufacturer sort problem cells. However, many battery manufacturers include a capacity discharge as a part of the manufacturing process. This testing makes factory ohmic readings redundant – capacity testing by definition is the measure of quality for a battery or cell. Where discharge tests are not part of the manufacturing process, ohmic readings may be used as a final screening before shipment. These readings are 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 **–** The use of factory supplied ohmic data is of little use to end users. In order to directly compare readings the cells must be in the same condition in the factory as in the field. In order for the data to be of any use, the readings must be taken while the cells are in a float-stabilized condition. Float stabilization can take weeks to months to accomplish. Barring this type of float characterization there is little correlation between factory and installed ohmic values. This is in addition to the differences due to equipment, technique, temperature conditions and state of charge that occur when two different measurements are taken in two different locations.

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 on internal connector corrosion, which generally 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 can not be used to predict absolute capacity values.

- Ohmic measurements can be used as a trending tool over time in field service to identify cells that may require further evaluation. Off-line capacity testing should be used to verify whether identified cells are in fact defective.

- Ohmic measurements taken at the manufacturing factory can be misleading and are generally 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.

- 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.

- 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.

- End users should contact battery manufacturers directly to discuss alternate uses of ohmic measurements.