ONLINE IMPEDANCE TESTING OF STORAGE CELLS

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Abstract:
An overview of the online testing of flooded lead acid, antimony or calcium cells and sealed lead acid valve regulated VRLA cells. The impedance studies have uncovered many weak or defective cells along with decimated intercell connections. This paper is a review of the type of data an operator may expect to see on good and/or marginal battery systems. It is suggested that data files be generated for each battery system. Then spreadsheets are developed to observe the periodic trends for the measurements. The operator should have an Excel program so that the data can be graphed for a more detailed analysis. The graphic analysis should show or lead to the development of base line reference values as they will be more exact then the average measurements taken on older battery systems. At the same time the data analysis can identify those cells that are aging faster then the other cells in the battery string.

HISTORY OF THE OHMIC "IMPEDANCE" TEST METHOD
The initial design for the battery impedance test method was developed for vented wet cells. The data generated from the test method allowed the operator to perform on-line and identify weak cells in the battery system in a short period of time. In addition the impedance data was used to establish the base line reference for future impedance trending. Commonwealth Edison developed the data for the impedance-measuring concept. See figure #1 for an overview of the historic profile of the impedance changes with the life of a cell or battery element.

The charts in Figures #1 & #2 are examples of the impedance life cycle of two different styles of battery systems. The % life will be influenced by the mode of operation. A critical aspect of the anticipated life is the ambient conditions in which the battery system will be installed. Has the battery user selected the correct battery type for the application?

The basic concept of the historic profile of the impedance changes through the life cycle of a battery leads to the base-line impedance level and the use of this data to estimate the end of life of a battery. The concept of impedance values is shown on figures # 3 & #4. The impedance values vary with the Ampere-hour rating of the battery along with the application for the battery.

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These two graphs are general information on the relationship of Impedance data that vary with the Ah rating of a family of batteries and how the impedance data can change with capacity within a group of similar cells.

This test method has been field tested at Industrial, Electrical Cars and Forklift applications
125 Vdc Substations  50 to  500Ah
25Vdc & 50Vdc Telephone  25 to  7000Ah
125Vdc to 600Vdc UPS Back  65 to  1350Ah
The range of cells tested span  10Ah to 7000Ah.

Field Test Results
These battery systems were tested on line on all but the fork lift trucks.
We have found that significant cell information is generated without having to equalize the battery system. When these battery systems are then given an equalizing charge, additional performance data is developed on the condition of those cells that do not show improvement impedance measurements.

ESTIMATING BATTERY CAPACITY
Impedance & load tests have been conducted on wet cells. With the calibration of the impedance data\(^3\) the operator can estimate the capacity of a battery system. Figure #3 depicts the impedance data vs. per-cent capacity plotted on a semi-log graph. Figure # 4 shows the relationship of the cell impedance values within a family of cells. The type of cell is governed by the application, it is not wise to mix AGM starved electrolyte cells with gel cells, as the internal impedance for the same ampere-hour capacity cell will not float correctly. The linear relationship of the data on Figure # 4 shows a impedance capacity relationships.

PRESENT DAY OHMIC MEASUREMENTS
With the increasing use of maintenance free, valve regulated cells known universally as “VRLA” units, the utilization of the impedance test method has expanded\(^4\). Specific gravity and electrolyte test measurements cannot be made on VRLA batteries. The impedance method allows test engineers to “look inside” the sealed containers and assess the condition of the operating cell or battery. It has proved an excellent way to uncover and address battery problems that could lead to catastrophic failures. The impedance measurement is an ideal test to perform prior to a load test. In addition this test can be performed on flooded cells prior to and after an equalizing charge. The lack of change in a cell’s impedance measurement can identify a weak cell.
DEVELOPING BASE-LINE DATA

The effect of increases in impedance varies with the type of cell under investigation. The original + 20% "rule of thumb" was developed by Commonwealth Edison along with Beta-site tests at N. E. Utilities about 10 years ago. The study on flooded cells correlated the impedance measurements with load tests.

The Slope of the Impedance Data for a Battery System at its rated Capacity will show a typical slope with in (+/-) 5% of the Cell’s Base Line Impedance value. These Slope profiles are evident on “Flooded & VRLA” battery systems. Note the “Flat Slope” of the Typical Graphs shown in Figures #1 & #2 have a similar profile.

The data plotted in these graphs, are the raw data from which Base Line Impedance value can be developed.

The graph in Figure # 6 illustrates an Impedance profile in which the capacity of the battery system is below its 100% rated capacity. The cells which are, loosing capacity, are noted as having a slope which show a higher per change from base line Impedance for the cells in the battery system

The measurements on the linear segment of the curve, are between (+/-) 5% Deviation can establish a base line reference value. The break in the slope indicates a group of cells that are aging at a faster rate then the other cells. These cell measurements are excluded when making the calculation for the Base Line value.

This was as found data; the battery system was not equalized prior to the Impedance measurements. This test method using “As Found” data advises the operator, that the battery system may require a “Equalizing Charge”. A second Impedance test after the equalizing charge can identify those cells that are active and isolate other cells that need further attention.

The Graph in Figure #7 illustrates the change over time with the average impedance of a group of cells.
It appears that the older battery systems that have a break in the slope above the 10% level, the lower the capacity of the battery system.

Additional Information has been developed on the capacity of VRLA batteries. The graph in figure # 8 shows the loss of capacity with increasing percent changes from base line impedance values.

The data displayed in Figure #8 is a summary of a number of tests performed on VRLA battery systems. The graph was based on the as found impedance data. This graph is similar to a report in which cells of different ages were tested for their capacity. The interesting aspect of that chart was the columns were labeled from “1” to 5-years for the first five-5 columns. This type of longevity has been documented from field studies.

**Conclusion:** The initial as-found impedance readings could be extremely useful.

1. The flat slope of the curve can be used to develop “Base-Line” data.
2. Major break points on the slope can represent cells of mixed capacity in the battery string.
3. High Impedance Cells are identified as candidates for a recharge, possibly single cell equalization.
4. If a battery system is on a critical load and the battery system has a major variation in the impedance readings, remote stand-by batteries should be connected to the load prior to shutting off the battery charger for a service test. The operational batteries would then be tested off-line, then recharged prior to the removal of the remote stand-by batteries.
5. The Battery Impedance Tests can identify which Battery Systems may have its capacity tests placed on an extended or foreshortened schedule.
6. Battery System with major variation in battery impedance readings can be identified as major candidates for reconditioning.

**Observation:**

1. The major physical problem in the battery systems, has been the poor attention devoted to inter-cell connections. The Impedance test method records this strap resistance data along with the Cell’s voltage and Impedance as part of the battery test program.
2. The float voltage settings are critical to the operation of the different type of cells. This data is collected as part of the test method.
3. The ripple current can be recorded for a more complete record of the battery system. This data is critical to the operation of “sealed Batteries” VRLA type.
4. The slope of the tests data can be compared from test period to test period to track the cells that are experiencing a fast change to a high impedance level, along with major changes in the inter-cell strap resistance changes or float voltage.

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1 Peter E. Langan Member IEEE SCC29 Battery Group.
2 Commonwealth Edison. C. Gabriel 1988
3 Battery Impedance – Single Cell Capacity Testing vs. Standard Every Cell Capacity Test Charles M. Gabriel and Kurt W. Uhlir – Commonwealth Edison Company
5 EPRI TR-08826, 106826 and 00248-R1 Batcom98
6 Sprint-United Telephone of Florida, Presented at the AVO Technical Conference Aug. 1994