MONITORING OF LEAD ACID BATTERIES

AN ELTEK WHITE PAPER

DIFFERENT METHODS OF PREDICTING PREMATURE CAPACITY LOSS

Gunnar Hedlund - 2013-12-19

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INTRODUCTION

No foolproof indicators/tools for knowing and predicting the health and life of a lead-acid battery have been evolved or devised. The only way to truly determine the health of a standby lead-acid battery is to perform a 100 % capacity test, according to the battery manufacturers discharge table. Such a capacity test means that the battery needs to be disconnected from the load and another back-up battery connected when the capacity test is performed. However, comprehensive controllers and instruments are now able to find failing cells without this test and while the battery system is online.

DIFFERENT METHODS TO PREDICT PREMATURE BATTERY CAPACITY LOSS

A large number of techniques have been explored and tried out in the field.
No single method or test instrument is capable of foolproof prediction about the residual capacity without performing a 100% capacity test. On the other hand, by combining some of them the state of health and expected residual life of the battery can be predicted more precisely and reliably. This is especially true in the finding of failing cells in a standby lead-acid battery.

Some of the techniques used for finding failing cells or predicting the state of a battery's health and expected residual capacity are:

A) Measurement of a significant deviation (>25%) in the Impedance, conductance or DC resistance of the cell as compared to the one recorded at the time of commissioning.

B) A partial discharge test with the battery connected to the load in which the voltages of each cell in the string are recorded in a test that involves lowering the rectifier float voltage below the open circuit voltage and discharging the battery with the connected load current.

C) Measurement and recording of cell temperature periodically.

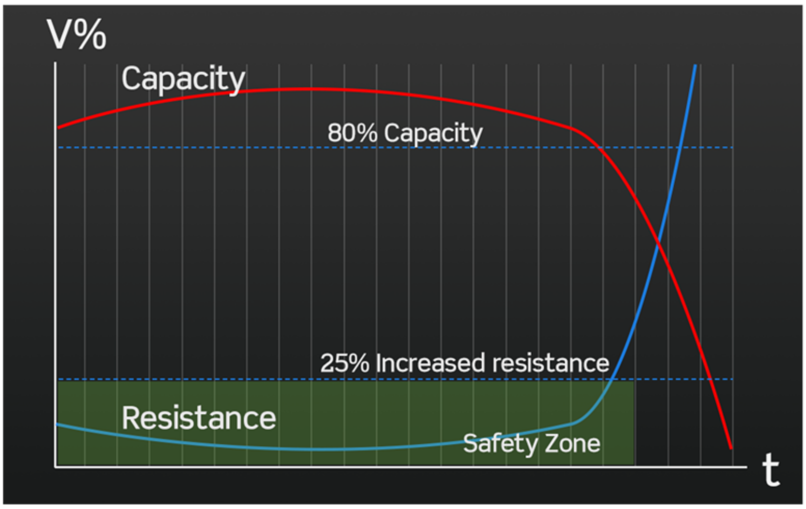
D) Measurement of cell voltage compared to midpoint voltage.

Measurement of a significant deviation in the impedance, conductance or DC resistance of a battery cell

There are different methods used in the battery industry to describe internal ohmic measurements:

– AC Impedance
– AC Conductance
– Resistance
– DC Resistance

All these methods try to find correlation between residual capacity and the given internal ohmic value. Normally, change in impedance/conductance/resistance of more than 25% could indicate a good or bad battery cell (see graph below).



The value of each cell shall be verified at the time of commissioning and shall be taken as the reference value. Different cells from different manufacturers or different lots from the same manufacturers will have different reference values.

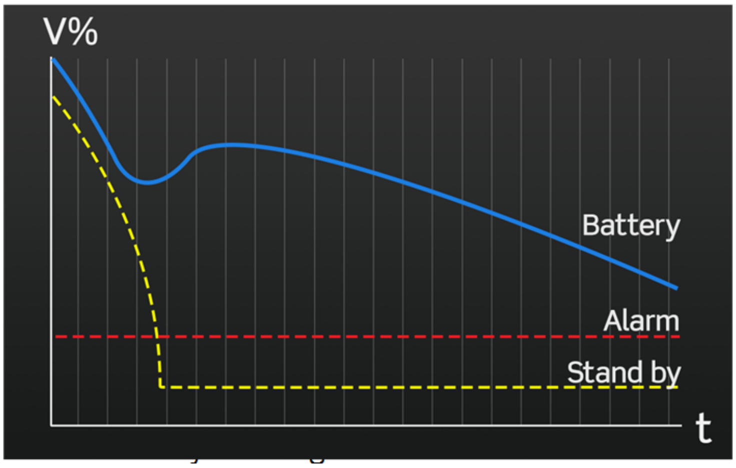
Experimental data show that the internal resistance within a batch of cells (from the same manufacturer) varies by about ±10% so that a residual capacity determination is afflicted with at least the same uncertainty.

Conductivity, impedance or resistance measurements should therefore be used as threshold value detectors (good – not good) instead of exact residual capacity detectors.

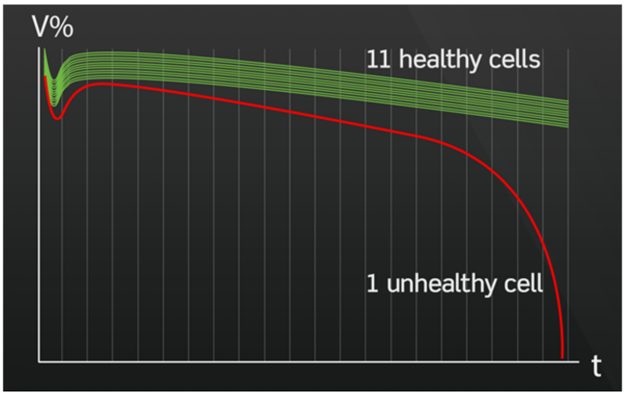
A capacity test is also recommended by the manufacturers of different test instruments for conductivity, impedance or resistance measurement if the readings differ by more than 20-30 % of the initial reference value.

A partial discharge test with the battery connected to the load

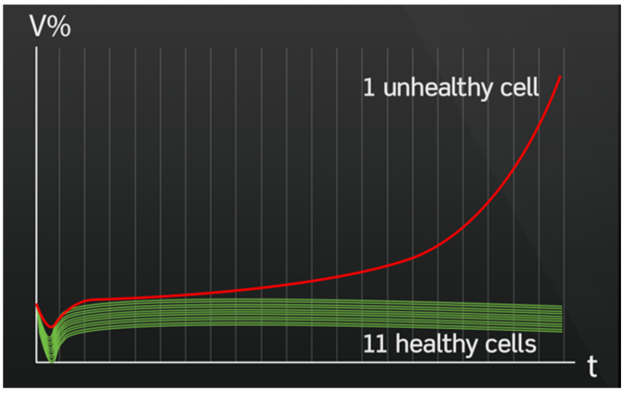
To evaluate the state of the battery bank, a partial discharge test could be performed by reducing the rectifiers' output voltage so that the batteries take over the full load current.



The batteries then become gradually discharged down to a specific end of discharge value. Usually a Depth of Discharge (DOD) of 30-50% is recommended to give a good indication of the residual capacity of the battery. However it is difficult to detect the failure of a single cell when only measuring the overall string voltage as the failed cell voltage will not manifest itself in the string voltage (see graphs below).



Individual cell discharge voltages



Maximum - individual cell voltages

The more cells that are connected in series, the more difficult to detect a failure of a single cell. The possibility to detect a failure of a single cell becomes more essential in a high voltage DC power plant with 50-120 cells in series (110-220 VDC)

Ongoing measurement and recording of cell temperature

The temperature at which the battery works is another important factor that seriously affects the life of the battery. The chemical reaction in the cell depends mainly on two factors: the charging voltage and battery temperature. The higher the temperature, the faster the reaction in the cell. It is also true that the faster the reaction, the battery will also have a higher level of active material shedding, gassing and grid corrosion. The gassing may indicate the onset of a thermal runaway in a VRLA battery.

The rule of thumb is that for every 10°C rise in temperature, the operational life of the battery is reduced by half.

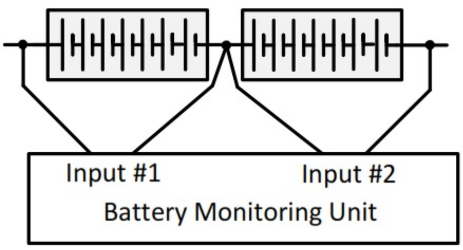
Temperature	Percent life
20°C/ 68°F	100%
25°C / 77°F	71%
30°C / 86°F	50%
40°C / 104°F	25%

In addition to temperature trending, battery health conclusions can be derived from comparing the intercell temperature of battery blocks or cell within the battery. It has been recommended that a 3°C temperature difference between cells is a suitable threshold for indicating the possibility of cell failure.

This is one approach employed during float charging for detecting thermal runaway in VRLA batteries.

Measurement of cell voltage compared to midpoint voltage

Some battery monitors measure the midpoint voltage of each battery string to detect voltage deviations within string. In this method, a monitor will create an alarm when there is a sufficient imbalance in the two half string voltages.



This method can be used to detect faulty cells during float charge or during a partial discharge test. However, it is difficult to detect the failure of a single cell when measuring the midpoint voltage in a high-voltage DC system with many cells in series.

CONCLUSIONS

Ohmic resistance readings cannot replace a discharge test to determine percentage 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 guaranteed 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.
The value of each cell shall be verified at the time of commissioning and shall be taken as the reference value, and it is essential to follow each cell as the reference value varies by about ±10% from the same manufacturer.

To evaluate the residual capacity in a lead acid battery, a partial discharge can be performed to 30%-50 % DOD. Controllers with battery management capability utilizing specific algorithms designed for various types of batteries are available.

With the possibility of measuring and detecting the failure of a single cell during a partial discharge test, this method can find a faulty cell without any ohmic resistance readings.

In addition to these methods, temperature readings of single cells could be a method to find faulty cells, especially during float charging for detecting thermal runaway in VRLA batteries.

Midpoint voltage readings of each battery string, to detect voltage deviations within a string can be used. However it is difficult to detect the failure of a single cell when measuring the midpoint voltage in a high voltage DC system with many cells in series.

SUMMARY

- 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.

- A partial discharge test with the possibility of detecting a failure of a single cell can find a faulty cell without any ohmic resistance readings.

- Temperature readings of single cells could be a method for detecting thermal runaway in VRLA batteries.

ELTEK`S APPROACH

Eltek's DC power system can be equipped with our state of the art Smartpack2 Monitoring and Control Unit. It provides a multitude of features that will improve today's operations and enable the operations of tomorrow. The Smartpack2 is easy and intuitive to use through its high resolution display, touch-pad navigation, and icon-based menus (depicted below in figure 1).

Figure 1 – Smartpack2 Monitoring and Control Unit

The controller provides comprehensive monitoring, reporting, and diagnostics, in a user-friendly format. In the event of an alarm condition, LEDs on the front of the controller provide immediate visual indicators of major or minor alarms, and whether power is on.

The controller has the ability to automatically store up to 10,000 events or data entries in its logs. This information can be an invaluable tool for understanding the sequence of events that led to a failure condition. By connecting a laptop computer to the controller, operations personnel can access this stored information and diagnostic messages from the system, enabling them to more quickly determine the root cause of the alarm condition.

The Smartpack2 can also be accessed remotely via Ethernet using a web browser interface. It supports SNMP protocol and enables the e-mailing of trapped alarms. It also supports a Modbus and IEC 61850 interface to SCADA systems.

Smartpack2 Battery Management Capabilities

The Smartpack2 includes extensive battery management capability. For example, the system provides automatic temperature-compensated battery charging, utilizing specific algorithms designed for various types of batteries. It also supports several automatic and manual boost charging methods.

Among the Smartpack2's advanced features is the ability to implement the various battery testing described earlier in this paper. There are several methods available for remotely or automatically initiating controlled battery discharges, which provide valuable information regarding the state of the batteries. The system will provide projections of battery capacity as well as remaining lifetime.

FlexiMonitor

The Smartpack2 can measure individual cell voltage down to 2 V/cell. Our new CAN-node FlexiMonitor also has the possibility to measure individual temperature readings of single cell or battery block.

FlexiMonitor

Each CAN node can measure up to 16 individual cell voltage or temperature readings with very high accuracy (10 mV, 1°C). It is possible to connect up to 14 CAN nodes to each controller which then can be used in high-voltage DC systems up to 220 VDC. The individual CAN nodes can be placed close to the battery for short voltage or temperature connections from an individual cell or block.

During a partial discharge test, individual logging of a single cell will be available to detect a faulty cell in the battery string. All readings of the individual cells will be stored in the controller and presented in the graphical user interface (GUI) of the master controller, or via the built-in web interface.

Controller battery test (monitoring) capabilities

- Evaluation of the residual capacity in a lead acid battery thru a partial discharge test with built-in algorithms designed for various types of batteries.

- Midpoint voltage of each battery string, to detect voltage deviations within string.

- Readings of single cell or block for detection of faulty cell or block in a battery string (with FlexiMonitor CAN node), up to 224 individual readings

- Temperature readings of single cells or block for detection of faulty cell or block in a battery string (with FlexiMonitor CAN node), up to 224 individual readings

REFERENCES

[1] Enersys Ohmic paper 8-05
[2] Monitoring of VRLA batteries guidelines GL/BAT-04/02 MAR 2007
[3] Standby VRLA battery behavioral predictions, University of Canterbury New Zeeland
[4] Herbert Giess Product Compliance document PCI1.13 SL
[5] Alber training and education, fundamentals of monitoring and ohmic measurements