WHAT IS THE VALUE OF A NUMBER?

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Introduction

This title may seem like a strange question, but it is one that is becoming more relevant as companies push to automate routine maintenance and the analysis of the collected data. Maintenance has always been about applying numeric values to operating parameters of the component being maintained. With that data, the component can be monitored by establishing limits, within which it is considered to be operating correctly. The problem is that these limits tend to be set at the edges of the operating regime to minimize false alarms and, as a result, that component may fail and compromise the system of which it is part, before the problem is identified. As many organizations are moving to the use of artificial intelligence to analyze the collected data, is the use of rigid numerical limits still the best way to assess the condition of an operational component? To examine this in more detail, let's look at the batteries of a standby power system as they offer one of the biggest maintenance challenges, as they are only called into service when the power fails, and a single-cell failure in a two hundred and forty cell UPS battery can cause the UPS to shut down.

Battery Maintenance

When the original versions of the IEEE guides to battery maintenance were written, they were based on calendar-based manual inspections and required human interpretation of the data. This worked well, as long as there were experienced battery technicians doing the work. With the breakup of the Bell operating system and the subsequent downsizing in the operating companies, the role of battery technician disappeared, and a level of expertise was lost. While the data was still being collected manually, it was now analyzed by only a few individuals, and the use of spreadsheets and limit alarms to identify potential failures became the standard. With the introduction of battery monitors over thirty years ago, the potential to collect the data remotely without human intervention became possible, and the supporting software replaced the need to use the spreadsheet to analyze the data. The use of limit alarms now dominated the analysis process, but has it worked? Regrettably, no. Of the three largest users of standby power systems - Communications, Utilities and Data Centers - the Data Centers are the only one that has done studies identifying the cause of unplanned outages and power system failure, and, in particular, batteries have topped the list. Let's look at this in more detail.

IEEE 1491-2012

1491-2012 - IEEE Guide for Selection and Use of Battery Monitoring Equipment in Stationary Applications identifies all the parameters that can be measured and provides guidance as to how they can be used to identify potential failures before they occur. These parameters can be put into three groups:

1. Those that are external to the battery but impact battery life,
2. The battery parameters that are considered static, as they can be measured at any time to track the battery's operational state.
3. Those that require perturbation of the battery to obtain a reading.

Charging, Environmental and Operational Parameters

This group of parameters - Charger Voltage, Ambient Temperature and the Number and Depth of Discharge cycles-can all contribute to the reduction of battery life. Of these three, the charger output voltage setting and the ambient temperature when operated in an environmentally controlled area are under the control of the user. So, they can use limit alarms to ensure that the battery is being charged within the manufacturers recommended range. The number of cycles that the battery is subjected to will have an impact on life as will operating the battery in a non-environmentally controlled area. The problem is that this is a function of the operational requirements and there are no realistic alarm limits that can be set. But the data collected can be used to calculate the impact on life due to the battery being operated outside its manufacturers' limits and to determine if a battery may require early replacement.

Cell Parameters

The problems start when we try to measure the operating parameters of the battery cells. Now we are dealing with an electrochemical reaction that responds in different ways, depending on the battery's operational state, age, and the interdependency of the individual parameters. This makes the use of limit alarms on specific parameters indeterminate when trying to establish a fault condition. Although all the parameters do provide information as to the battery's State of Health, no single parameter can determine whether the battery will support the load, if placed on discharge.

Ohmic Measurements

The use of Ohmic measurements started with the introduction of the VRLA battery, when the traditional methods of battery maintenance, such as inspection of the plates and measurement of specific gravity, were no longer possible. The objective was to measure the change in the internal resistance of the cell as it ages. Unlike the other parameters listed in IEEE 1491, in order to measure the Ohmic value of a cell, you must pass a perturbation current through the cell (or cells, if it is a multi-cell unit) and measure the response. Because the frequency and level of perturbation current is specific to the manufacturer of the test equipment, the value reported for each cell will be different depending on the test equipment used.

Baseline

To measure that change in resistance for each cell over time, a baseline must be established, and that will be used to determine the change in ohmic value on subsequent readings. The baseline is typically a set of stable readings taken after the battery has been in service for a period of time. In the early days of monitoring, it was thought that the change in ohmic value could be used to indicate capacity and end of life. Since the introduction of ohmic measurements, a rise or fall of between 30 % to 50% has been used to identify the point at which the change in ohmic value of a battery would indicate end of life. While it was subsequently shown that ohmic measurement did not directly relate to capacity or end of life, these figures continue to be used as limits, for the change in ohmic value, at which further investigation is needed to establish the cell / unit's state of health.

Analysis Software

Although the change in value over time is the metric that we need for analysis, the software supplied by most test equipment manufacturers simply reports the current ohmic value for each cell/unit and plots it with respect to the baseline, using the established alarm percentage rise value as the limit alarm. There are two ways in which these alarm limits can be calculated, either as a separate alarm value for each cell, as shown in Figure 1,

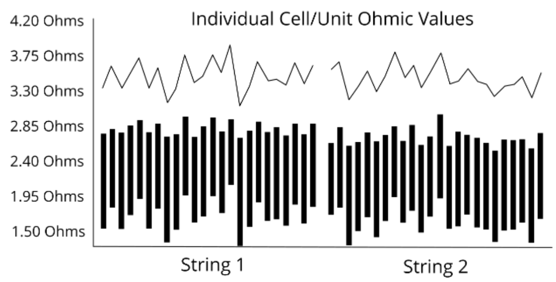

Figure 1

or in some cases, to simplify the process, other versions of the analysis software calculate an average ohmic value from the initial baseline and use that to establish a common alarm value for each string. The problem with that, as can be seen in Figure 2, is that some units will alarm before they have increased in value sufficiently to reach their alarm point, and others will be past that point before they are in alarm.

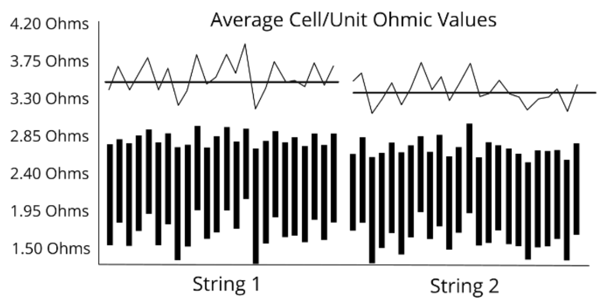

Figure 2

While this approach to analysis worked when the test equipment was from a single vendor, the fact that the numerical values for the ohmic values will differ for each manufacturer means that the collected ohmic data is not comparable if the test equipment changes. The question is, can we make the data comparable between manufacturers?

This is not a hypothetical question but is a problem we face today with the increasing use of monitoring. When you move from manual maintenance to a permanently installed monitor, the historic values and limits are clearly not directly transferrable, yet we do not want to lose that historical data as the basis of further analysis. Rather than using the ohmic measurement as a point on a graph, had the software calculated and reported that change in ohmic value as a percentage change from the baseline, that value would be common to all monitors, irrespective of the equipment manufacturer. But all is not lost! With a little help from a spreadsheet, we can use the historical data to establish a new baseline that reflects the changes in ohmic value that occurred during the period of manual data collection.

Resetting the Baseline

By taking the first (or better yet the baseline reading, which is typically taken 3-9 months into useful life) and the last set of the historical readings, we can calculate the percentage change for each cell/unit within the battery. If we then take the readings from the new monitor and deduct that percentage change from each cell/unit, we will create a new baseline for the monitor that will replicate the old data. While this will at least ensure that the historical record will be retained within the existing software, we still do not have a have a common value across all batteries that can be easily compared. Why is this important?

Rethinking Monitoring

Historically, battery monitoring systems have been standalone and managed separately from the overall monitoring and management structure of an organization, but that is changing. With the increasing focus on the use of artificial intelligence (AI) for operations management, the battery monitor will ultimately become another smart sensor that communicates with a centralized monitoring and management software using a common set of data, irrespective of who manufactured the monitor. This requirement for a common reporting structure is essential, in order to allow the use of AI software to identify changes in patterns and relationships within the network that will identify the risk of potential failure.

Next Generation Analysis Software

As we determined earlier, the cell-related parameters are very dependent on the operational status of the battery. So, when the data is manually collected, the objective is to take the measurements when the battery is fully charged and stable, in order to record the data for easy comparison. With a monitoring system, the data can be collected, irrespective of the operational status, which means that a lot more data is available under all operating conditions. With this data, the relationships between the individual cells/units can be monitored and changes in those relationships recognized. This idea of using patterns and relationships as a key part of the analysis process is not new. It always has been part of the human assessment of the collected data, as it provides a way to identify those cells/units that may not have reached any of the preset limits but are changing with respect to the other units in the string, indicating the potential for early failure.

As we have seen with the ohmic measurement, measuring the percentage change of the parameter and the rate at which it is changing can provide a common base, on which comparisons can be based. If we apply the same methods to the other measured parameters, it will allow us to detect changes in the individual cells/units, irrespective of their operational status. In that way, we can automate much of that human analysis that is currently missing. Once we have the monitor providing that first stage of analysis, the network AI software will then be working with a common set of data for all locations and allow it to make the required network-based decisions.

So, what is the value of a number?

As we have seen within a battery monitor, if we use the data collected from the individual battery parameters in the numerical sense, then the individual parameters are limited in what they contribute. But, if we use these values to generate other values that more closely represent a change in the battery chemistry, then the value of that number is more closely associated with another definition of the word “value” and, to quote the Merriam-Webster dictionary, “something intrinsically valuable or desirable”, and perhaps that is the true meaning of value in this context.

References

1. INTELEC 94 The use of ratiometric measurements to determine battery status.
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