BATTERY MONITORING...3 SHORT STORIES

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INTRODUCTION

The role of monitoring process and equipment has been around since the industrial revolution. In ever increasing spirals of demand and sophistication, everything including stationary batteries is fair game for some form of monitoring. The most intelligent of these monitors is the educated human with sufficient relief for rest and nourishment. Beyond that, forms of machinery and electronics, assisted by software intelligence perform the majority of monitoring duties.

The competitive business theater today has placed demands on the human work force that necessitates assistance from the hardware and software based alternative. Stationary batteries, as the lifeline for UPS and power quality equipment, has landed in the middle of such a monitoring scenario. If space (real-estate) were not a problem, long proven vented cell designs would dominate in all applications. If sophistication of end user equipment had not required an increase in support from the maintenance staff, the battery technician would be prevalent in maintaining these batteries on-site.

The cold facts are that this maintenance process has been relegated to third party process and/or some perfunctory monitoring device. The question has always been, when is the monitoring solution sufficient? The answer has been addressed commercially by several battery monitor vendors who have offered an array of solutions. Some new technologies have evolved, such as impedance testing and thermal imaging but they often provide additional data to the data that has essentially been ignored before. In other words the human element remains in place. Is it the Battery Monitors role to replace this human element completely or assist in more diagnostic measures?

As a battery monitor vendor, such questions are asked of our customers and sometimes the answer is incomplete. Translated this means "How much does it cost me?". As a means of response, BTECH has kept pace with individual requests but an industry wide standard is sorely needed. In the past the battery monitor consisted of a voltmeter on the dc bus, throw in some ground fault detection and the battery professional could sit back and relax. Well, not really since he quickly learned that 80% of all battery failures are connection path related. So, he required a flashlight some intuition and due diligence with his maintenance routines (IEEE 450).

Leaping ahead to today's monitoring solutions, we have access to various forms of battery parameters and have the capability of determining when things go wrong. We can then track the events and illustrate in graphical detail the systemic demise of the battery system as it happens. Sort of a black box mentality. I am sure it provides some comfort to the battery professional to see the results of a problem but he would more likely appreciate forecasting this type of problem ahead of time.

This becomes the dilemma for monitor manufacturers. Capturing data is a given but the exercising of this information and reflecting it as some type of causal relationship with the battery is controversial. When to alarm, and to what degree. The popular alarm method is to provide some comparative level or threshold where once crossed, it provides the alarming feature. This data can be preset by the manufacturer , confirmed by the battery supplier and ultimately edited by the annoyed end user responding to the alarms. Providing some diagnostic intelligence moves the monitor closer to the former manual surveillance technique. In that former maintenance regime, attention to trending data was instrumental in catching small problems before they turned into unfortunate events. The answer therefore is to provide alarms on delta changes of specified parameters to warn the maintenance provider before critical thresholds are reached and unfortunate events become a career issue.

BTECH has initiated this type of alarm feature with its latest version of BVM 2.1 software for Windows based operating systems. The following case studies illustrate successes in locating faults with due diligence of observation and utilizing diagnostic calculations within the software package.

CASE 1

A manufacturing concern on the west coast of the US has used the battery monitor to exact as much duty from the battery system protecting their process control as possible. They perform this knowing the risks involved but they feel that their knowledge of the VRLA battery type history and the reliability of the monitoring device allows them to reduce the odds of unplanned outages and exact financial gain from their capital investment. The battery system consisted of five parallel strings, each containing 32 six cell monoblocs (jars). As of March 3rd, 1997 all monoblocs were within manufacturers float voltage limits with an average of 13.63 volts. However, four units were exhibiting impedance values above maintenance limits set by the monitor manufacturer (10%). Three, including unit 64 were above the critical limits selected (15%) at 30 % or better.

This particular 6 cell monobloc battery (#64) has exhibited a higher impedance from normal since the monitor was installed.(See figure 1) Unfortunately battery monitors seldom make a suspect cell any better. They may point to environmental and conditioning factors but once a cell is in its downward spiral of life, there is only the reporting of degree. The owners decided to utilize the slope level alarm since the suspect monobloc already passed through the critical transition alarm set for the battery string. The resultant figure 1 illustrates the trend of impedance for unit 64. As of March 3rd, 1997 the unit consistently alarms as a slope value of 10 μΩ per week is exceeded and the value was 35% above its critical limit. Interpreted this means that it is 45% above the impedance for a new jar, 2.5 μΩ. Since the battery manufacturer has graciously agreed to replacing the defective unit at the 50% point, and the trend is safely linear, a new unit was placed on order based on the information provided by the battery monitor.

It is nice when items under observation trend nicely linear with a grand degree of expectation but the reality of items capable of change is that the degree of variance can become excessive at a moments notice. An appropriate example follows.

CASE 2

The owner of this VRLA battery string had similar philosophies concerning replacement of the batteries as the owner in Case 1. This should come as no surprise since they both belonged to the same corporate parent. The interesting facet of this data is the length of time that the battery monitor has been observing the system and recording the performance. Voltage and impedance data are documented for three and a half years with the understanding that the monitor was placed on an existing battery system. The approximate age of these monoblocs was five years from the latest data point. The battery system consisted of four parallel strings, each containing 34 six cell monoblocs (jars). No temperature excursions were documented and the system was charged at constant float potential with an occasional boost charge applied.

Float voltage performance of this monobloc has been stellar with no recorded deviation from ideal (13.65vdc). The only discharge history was from a two minute outage in 1994. Because of the criticality of the site and power system, the units do not have any load test history other than acceptance testing. The harsh reality is this is the typical working situation in which batteries and their monitors need to exist. As expected, over the lifetime of the battery string, the impedance values would rise as the cells age. This is normal as the cells age, dry out and/or lose capacity. The string average of impedance values parallels the unit impedance performance shown in Figure 2. The negative excursion in February of 1994 was caused by a blown fuse in the monitor.

The graph in figure 2 points out the benefit of utilizing the slope method of alarm as unit 45 slowly diverges from the string average and rapidly accelerates at a rate of over 25 μΩ per week where as months prior to this excursion, the unit was below the alarm threshold in average mode and only creeping up at an 8 μΩ per week rate. The decision to await battery replacement had been made under similar considerations as in Case 1 but had to be re-evaluated after the impedance excursion in July of 1996. External connections were checked in order to eliminate non-cell related causes for the rapid rise in impedance. These could include dirty or loose cell connecting straps or corrosion on the posts. All was found to be in order and it has been concluded that the jar has diminished conductivity due to plate separation from the electrolyte. Because of the similarity in trending among all of the monoblocs within this battery system and the age of the jars, the decision is being made to replace the entire battery.

Without this added degree of surveillance and analysis, an incorrect decision on replacement criteria would have been established and may have caused a serious loss of protected power at some point in time. A further important point is that the diagnostic information received did not come at the expense of time constraints on the user. I am sure that a load test would have established replacement criteria quite rapidly but in practical terms, this test would never take place in this manufacturing environment. A momentary load placed across the cell may have picked up a weak cell but only after the impedance had increased dramatically. A positive result of one of these type checks would have led to false security. A negative result would have resulted in the removal of the suspect jar only.

CASE 3

Sometimes the changes are more subtle. A financial institution on the east coast of the US used two cell and three cell jars to make up a two parallel string VRLA battery system. The two cell jars resided on one string and the three cell jars resided on the other parallel string. Economy dictated that the monitor address both strings and be connected at the jar level in order to minimize the number of connections to the battery system and minimize the investment as well.

The UPS cells were of low impedance and the concern was that the impedance value may not be of sufficient resolution to warn of impending problems. The alarm settings for the voltage and impedance values had to accommodate the spread of the two type jars installed so the error would have to be somewhat large in order to alarm. A one week shutdown was planned annually so the dc system had to be securely forecasted to the next maintenance period.

This particular monitor was installed before the vendor software, BVM 2.1 was available so the only resolute method of determining movement in any of the measured parameters was human interpretation. As my opening statement suggested, this solution was only acceptable for a short period of time. After several months and the batteries behaving properly, the tested data was ignored on a regular basis.

The introduction of monitoring slope variation to the observer software proved useful to this customer and was added in the Fall of 1996. Figure 3 shows the life cycle of this particular 3 cell monobloc which has exhibited variations in voltage and impedance parameters. The dotted line represents the initial value determined at the time of monitor installation. As with new cells, the impedance value moves about in the infant stages of battery formation, usually settling to a value below that recorded at inception. This battery unit exhibited such a profile and developed a positive trending a year later.

Because of the wide alarm limits for both voltage and impedance, any transitions would be neglected for a long period of time. Fortunately the delta alarm for impedance was set quite low at 5 $\mu\Omega$ per week and the impedance increase was noticed. Unfortunately, the attached UPS repeatedly took an energy bite from the batteries and created fluctuations in the weekly impedance readings because of state-of-charge influences. But the polynomial trend line shows a positive climb.

Although the last recorded impedance value only represents an eighteen percent (18%) shift, the delta alarm actually placed a spotlight on the unit's voltage performance. The manufacturer's float voltage swing is $\pm$ 0.10 volts per cell and would produce a unit float range of 7.08 to 6.48 volts. The last float voltage level of 6.72 is far from the set minimum but an indication of trouble ahead is recognized. And this is the benefit of battery monitoring with forecasting capability. As this customer approaches his one chance for maintenance per year, he can assimilate the data provided and determine his odds for continued performance through the following year. He now becomes that educated battery professional without the required dedication to the science. Conversations with battery manufacturers and power equipment vendors is more productive and should result in better service from these providers.

SUMMARY

The cases illustrated above do not portray violent, spectacular, fire-in-the-sky battery problems that some papers report. No buildings were destroyed by ignited hydrogen gas or evacuated because of spilled electrolyte. Rather they illustrate that prevention goes a long way if the information received is timely, reliable and repeatable. Conscious battery replacement decisions were made based on hard data and the financial constraints imposed at the time. An argument can be posed that given enough time to develop, these problems would have surfaced eventually and may not cause any load or personnel liability. One also could argue that they could and this paper would have addressed catastrophes. However, the decision to place monitoring equipment on the battery systems of the power lifeline for the two critical manufacturing concerns and one financial institution demonstrated that any interruption of power was unacceptable and surveillance was required.

The task of culling out these bad battery units was greatly enhanced by developments in the software provided with the monitor. The alarm on trend (delta) further addressed the shrinking time budget for these maintenance (or not) professionals by providing assistance with some of the diagnostic chores. Turning the battery system observation over to a third party was not an option in these cases but if it were, they could simply specify a similar surveillance technique.

Reviewing hundreds of monitor installations for this paper, it was clear that despite the engineering involved with the data measurement and collection, the dissemination of that information is key to the user. There happens to be a unique opportunity to provide guidance to the industry as a whole for battery monitoring solutions. The IEEE has recently approved work on a document to be titled, "*Guide For Selection And Use Of Battery Monitoring Equipment In Stationary Applications*". The task force formed is under Standards Coordinating Committee 29 and meets twice a year in the Fall and Spring. Our counterparts in Europe under the IEC have issued a suggestion for a document entitled "*Guide for the use of monitoring systems for lead-acid stationary batteries*" and operates under Technical Committee 21. Depending on your geographical preference, it is this author's hope that the curiosity shown by reading this paper carries forward to participation with one of these technical groups and contributions to the resultant documents.

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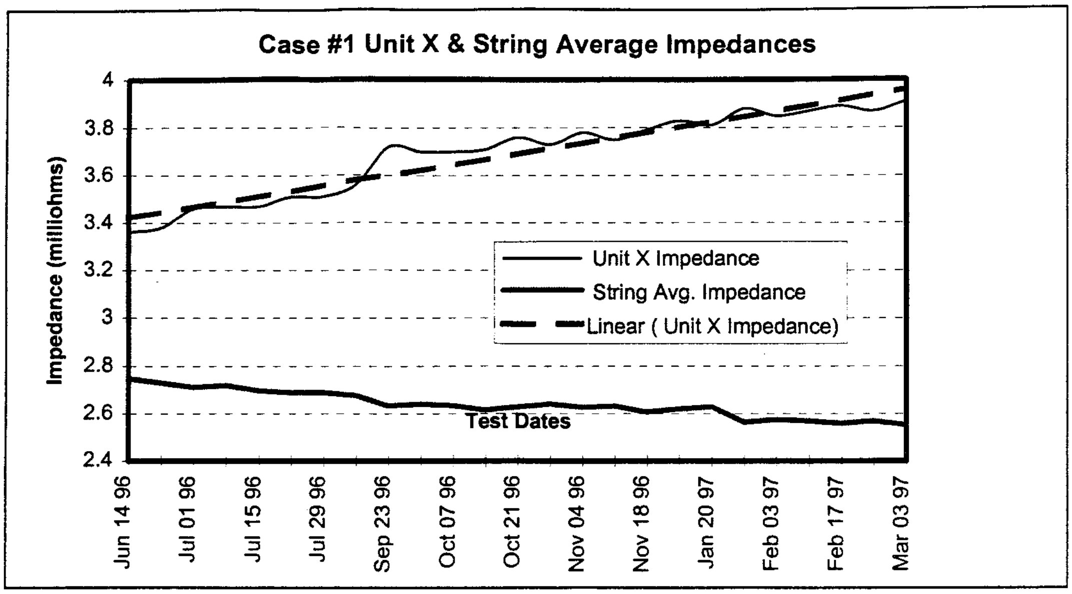

Figure 1 **Case 1 Unit & String Average Impedance**

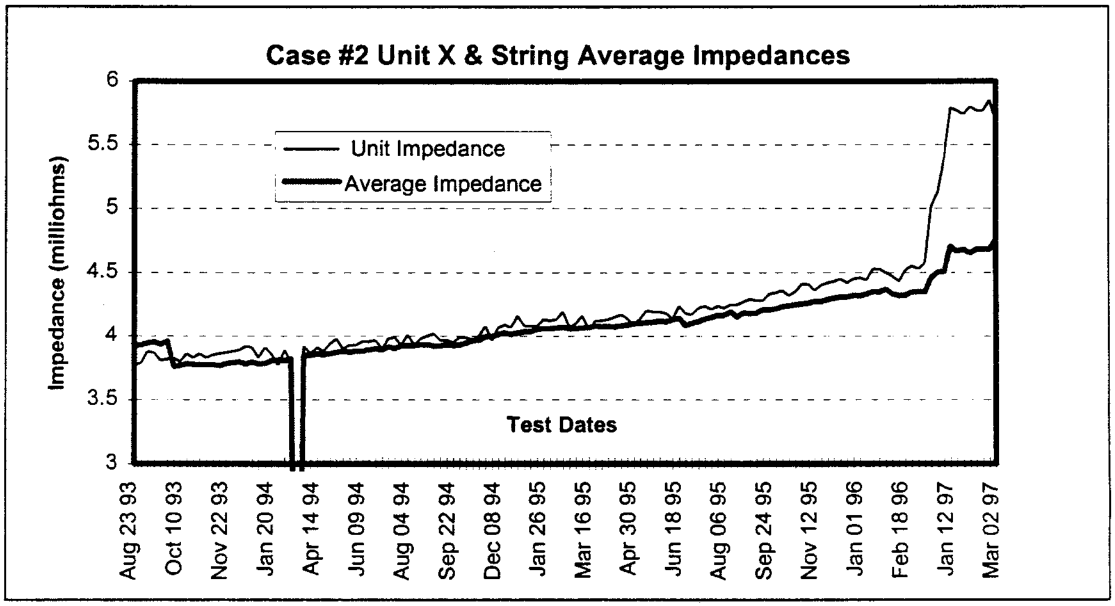

Figure 2 **Case 2 Unit and String Average Impedance**

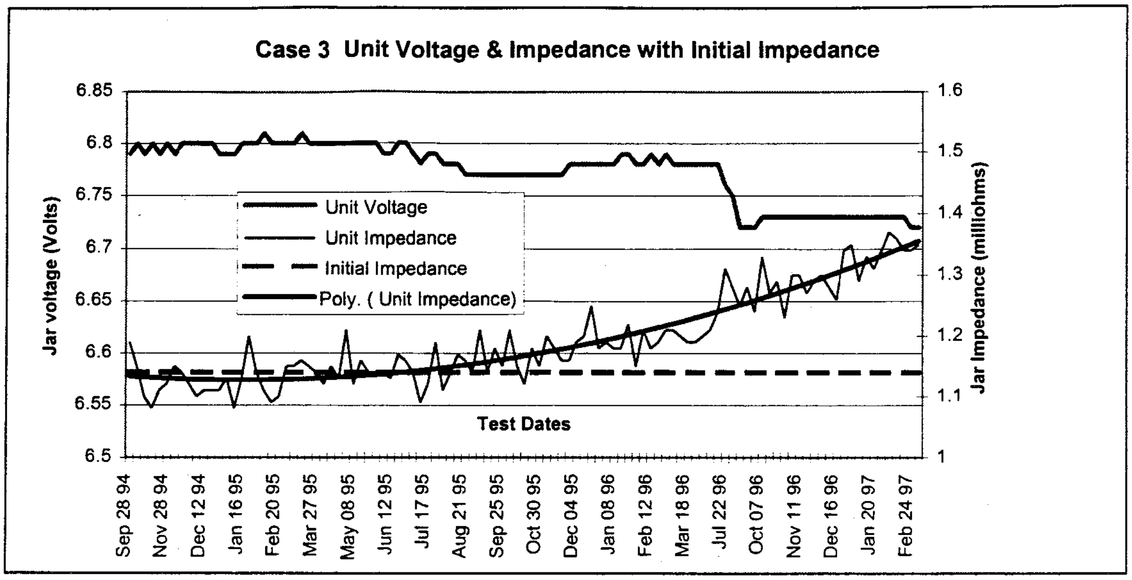

Figure 3 **Case 3 Unit Voltage & Impedance Performance**