AIR FORCE EXPERIENCE IN BATTERY MONITORING

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ABSTRACT

The United States Air Force (USAF) has been fielding power-conditioning equipment for over 30 years. The main piece of equipment in the last 15 years has been the solid state uninterruptible power supply (SSUPS). With the introduction of the Valve Regulated Lead Acid (VRLA) battery the need to determine the health of the cells was realized. This paper will cover the history of battery monitoring conducted by the Power Conditioning and Continuation Interfacing Equipment (PCCIE) office and Air Force Research Laboratory (AFRL), values used in analyzing cells and how they were derived, and experiences in monitoring.

BACKGROUND

The PCCIE office is responsible for providing power quality solutions to the USAF sensitive electronics equipment systems mission. Their mission is to provide cradle to grave, single face process management to the customer. Power Conditioning and Continuation Interfacing Equipment Special Maintenance Team (PCCIE SMT) had the capability to install, maintain, troubleshoot and repair UPS and battery systems. The PCCIE SMT also provided technical support for the PCCIE engineers and sustaining engineering efforts, quality control for equipment warranty actions, performed site equipment surveys, and reviewed technical specification for acquisition contracts. The PCCIE office started monitoring UPS batteries in 1994. Several systems were purchased, installed and the monitoring began. Data has been collected from 15 Air Force sites consisting of over 3,000 cells during the last 6 years. As data was collected the PCCIE SMT analyzed the information. Discussions were conducted with battery and battery monitoring systems manufactures. The PCCIE SMT started using the default values in analyzing the data due to the number of different models of batteries being monitored. The default values required changing. Over time the PCCIE SMT concluded the data listed below which was used in monitoring parameters. With the pending closure of McClellan AFB and the decision to convert the PCCIE SMT from military to civilian AFRL became involved in the monitoring to make the transition flow smoothly without the loss of expertise.

MONITORING PARAMETERS

PCCIE and AFRL use the following monitoring parameters to evaluate UPS batteries.
Max Float Voltage 2.40: When cell voltage reaches this limit it will be replaced.
High Voltage Alarm Point 2.36 volts: At this point we monitor the voltage trends closely if the voltage continues to increase we will recommend contacting the maintenance contractor for replacement.
Nominal Float Voltage 2.25: Due to the large numbers of cells monitored we use 2.25 Vdc as a nominal float voltage value for all cells.
Low Voltage Alarm Point 2.14 volts: At this point we monitor the voltage trends closely if the voltage continues to decrease we will recommend contacting the maintenance contractor for replacement.
Min Float Voltage 2.10: When cell voltage reaches this limit it will be replaced.
Internal Resistance Alarm points 25% of initial value when battery was installed: When a battery or battery monitoring system is installed an initial set of values is recorded for comparison through out the life of the cells. When a cell exceeds 25% of that value we monitor the cell closely and advise the user. Remember that during the first year of a cell life is a breaking-in period and the internal resistance may change.
Internal Resistance replacement value 35 to 50%: A replacement value of 35 to 50% is a wide range however the size of the cell will determine how fast the internal resistance may increase once it starts.
Battery Temperature between 72° and 78° F: This parameter is set by the battery manufacturer. The temperature of the battery room may be colder however the charge rate of the UPS should be increased to compensate for the colder temperature.

EXPERIENCES

The following are actual experiences at USAF sites.

Experience 1: Site Description: 250 Kva UPS with 5 parallel battery strings, consisting of 31 containers, 6 cells per container (totaling 930 cells). The battery manufacturers service personnel replaced three of the 5 parallel battery strings. During installation of the 3 parallel battery strings 2 containers were identified as being bad due to low voltage. After the installation was completed, the installed battery monitoring system identified a third container with an internal resistance 50% above the average of the new containers. All three containers were removed and returned to the manufacturer for testing and tear down to determine the cause of container failure. Discharge tests were performed followed by tear down of the containers. Testing and tear down indicated there were no problems in any of the three cells. A good initial charge or an equalize charge may have prevented the replacement of the 2 cell which had low voltage. The third cell with initial internal resistance 50 % above the average was above manufacture specification. Figure 1 shows the average internal resistance of the new strings of the battery compared to the container with the internal resistance 50% above the average over a 3-month period (3 Aug – 19 Oct).

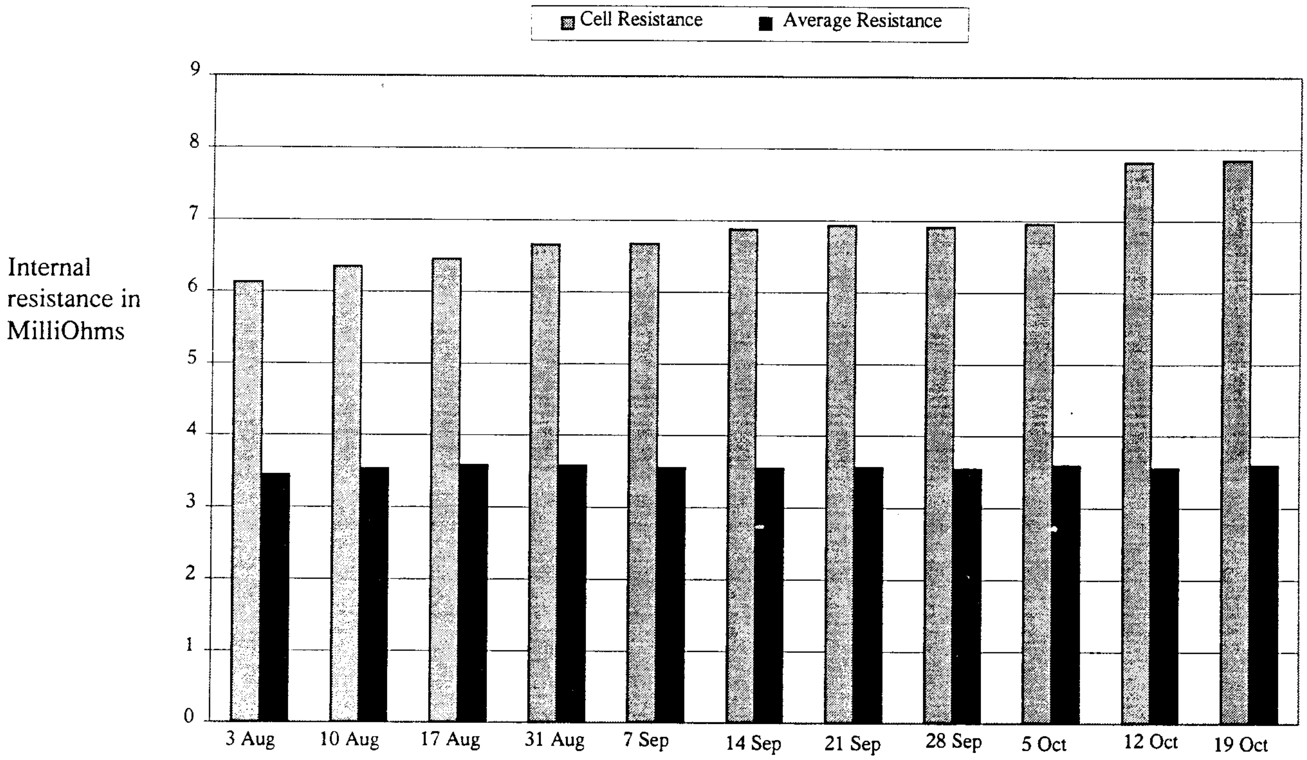

Figure 1: Comparison of the average internal resistance versus the cell with 50% higher internal resistance.

Experience 2: Site Description: 5 - 1,000 Kva UPS in parallel. Each UPS has its own battery consisting of 240 cells. Data has been collected since Oct 1994. Out of the 1,200 cells only 4 have been replaced.

The manufacturer maintains the installed battery monitoring system and the UPS and batteries are maintained by the UPS manufacturer. The UPS manufacturer service personnel perform maintenance that included cell voltage and internal resistance, which are reported to the user. The installed battery monitoring system reads battery voltage and internal resistance weekly and AFRL provides the user with a monthly report. In April 1998 the internal resistance of cell 226 started to increase at a rate of 3% per month indicated by the installed battery monitoring system. Figure 2 shows the increase of the internal resistance over a 17-month period (Apr 98 – Aug 99). The installed battery monitoring system showed the internal resistance increasing as much as 10% per month. The UPS manufacturers service personnel perform maintenance with the use of a hand held instrument that records battery voltage and internal resistance. This is accomplished every 6 months. The maintenance inspection performed during the month of Aug 98 reported all cells were within tolerance. During the second battery inspection (Feb 99) all cells were reported to be within tolerance. After the third battery inspection (July 99) it was decided by the maintenance contractor to replace cell 226. The semi annual inspections picked up on the increase of the internal resistance over a year after the internal resistance started to increase. In summing up this experience the installed system identified the problem early on and the cell could have been replaced at any point during the 17-month period. On the other hand the UPS manufacturers service personnel also identified the problem before the cell failed. No one can determine when a cell will fail however the sooner you identify a problem the sooner you can take an action.

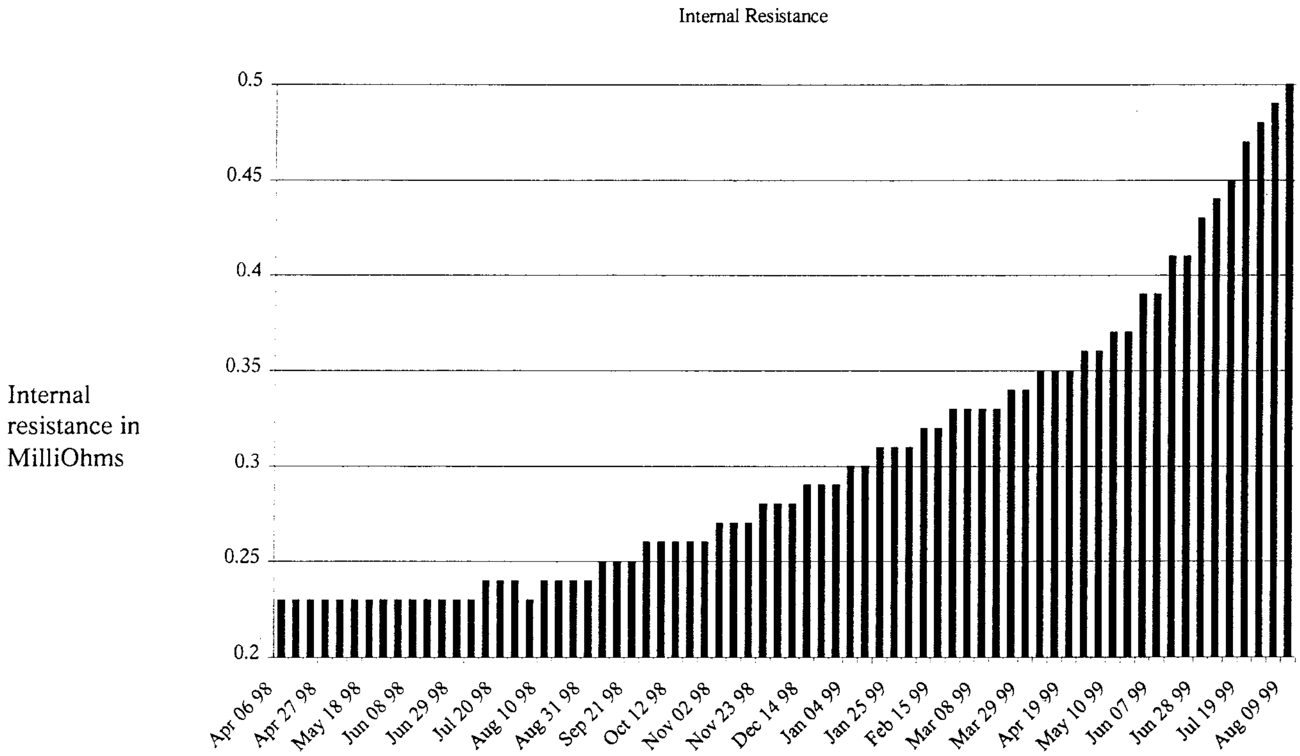

Figure 2: Internal resistance history over 17 months.

__Experience 3:__ Site Description: Single module UPS with one battery consisting of 48 containers, 4 cells per container (totaling 192 cells). Figure 3 shows the internal resistance of cell 43, which started to increase. As a cell ages the internal resistance increases. Once the internal resistance increases above 25 % the cells will be monitored more closely. The rate of increase and the size of the cell will determine when the cell will be replaced. The container in this example weighs about 800 pounds and has 4 cells. This size container has a large amount of lead when compared to a 6-cell container approximately the size of the battery in your car. Internal resistance in a large cell will increase at a slower rate than a smaller cell. We also need to keep in mind the cost of cell replacement. A cell may be replaced under warranty at a prorated cost depending on the number of years in use however the user still pays labor and travel expenses. Now that we have several variables (age, rate of increase in internal resistance, size, and cost) we still need to determine when to replace the cell in question. In the case of cell 43 (figure 3) it is too early to determine whether the increase is due to normal aging or the cell is going bad. We don't want the user to replace a cell unnecessarily so it will be watched until the internal resistance rate of increase is sufficient to cause concern.

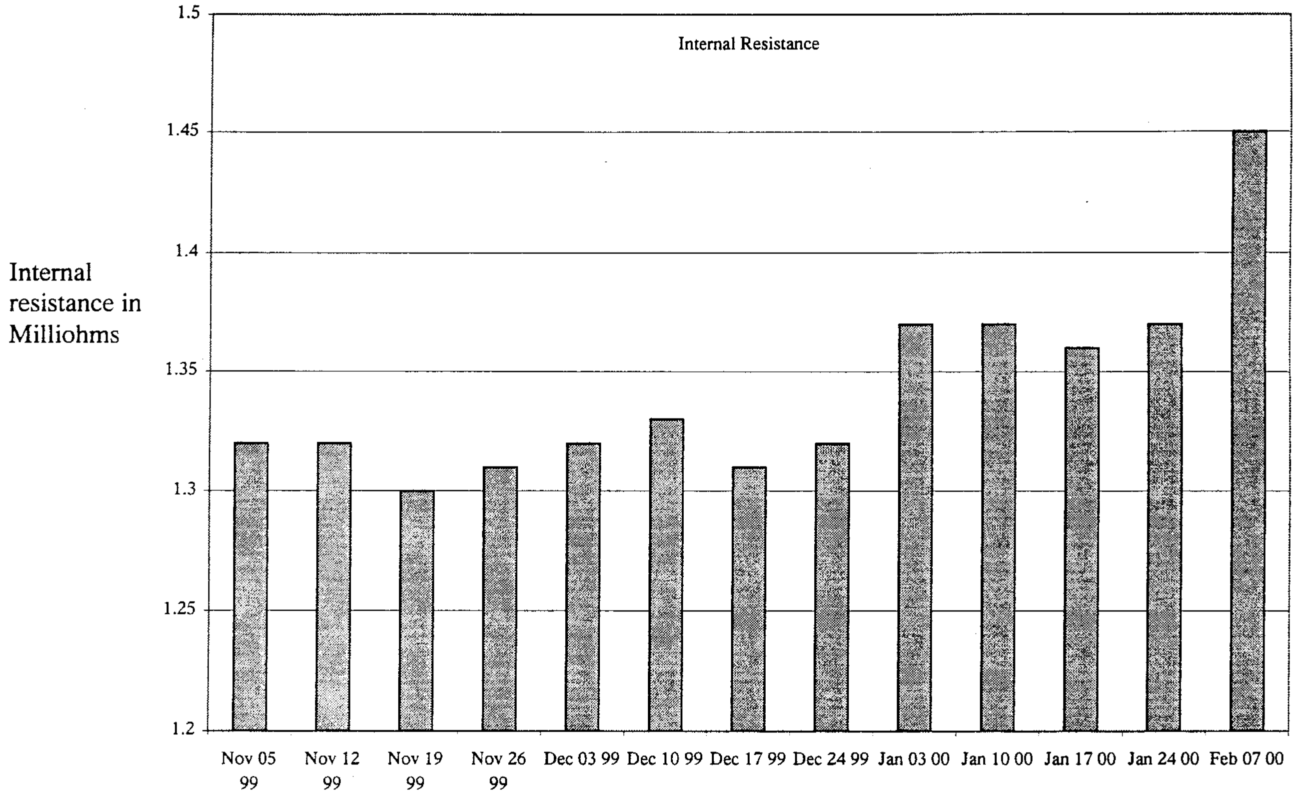

Figure 3: Internal resistance starting to increase.

Experience 4: Effects of Temperatures: Single module UPS with one battery consisting of 48 containers, 4 cells per container (totaling 192 cells). Figure 4 shows the temperature of the battery over a year (Sep 98 – Sep 99). High temperatures increase available capacity but decrease life expectancy while low temperatures have the opposite effect. This site has been lucky; so far they have not replaced any cells since installation in 1997. It is just a matter of time until they have major battery problems.

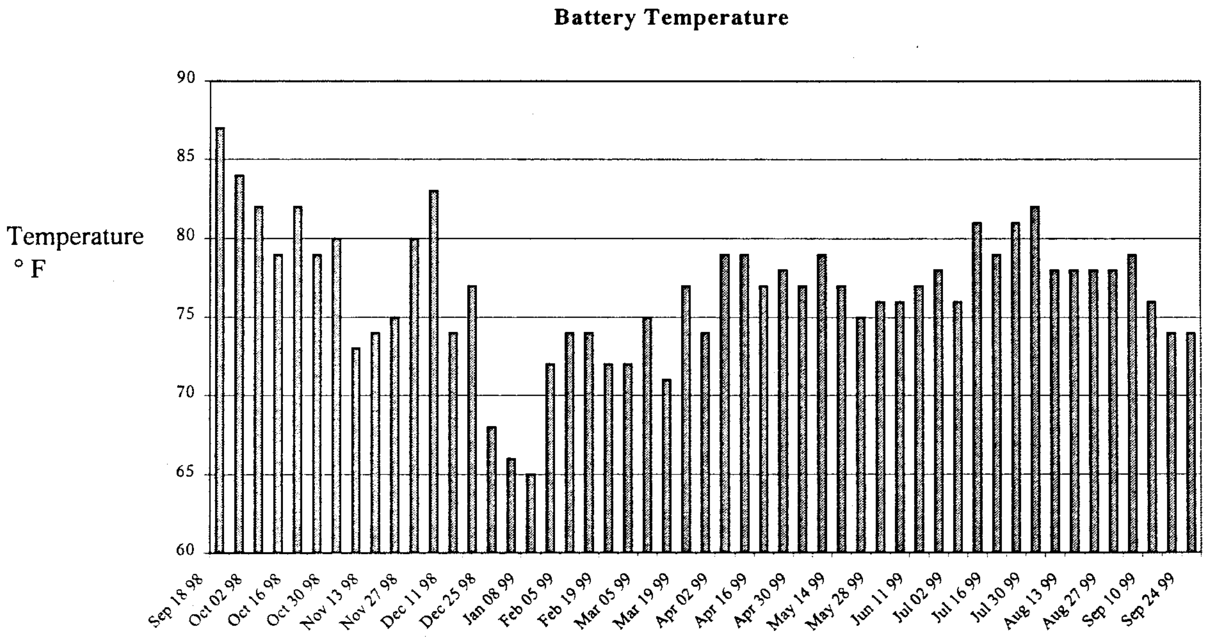

Figure 4: Temperature in ° F over a year's time.

Conclusion

The PCCIE office and AFRL realize that battery monitoring is needed to insure reliable battery systems; however, battery monitoring is an indicator to the health of the battery and individual cells. A good battery-monitoring program can save mission down time, unnecessary cell replacement, and expensive battery load testing. The load test will determine if the cell or battery needs to be replaced. There are times when the replacement of one or two cells is more economical than the cost of a load test. At these times a good battery-monitoring program will pay off. The PCCIE office and AFRL collected data from 15 Air Force sites consisting of over 3,000 cells during the last 6 years. The program has identified 15 cells for replacement however; this does not include complete battery replacement.

Future Efforts:

Since the phasing out of the PCCIE SMT and the relocation of the PCCIE Program office to Hill AFB, battery monitoring responsibility remained an issue. The solution was to hire and train a new team of civilian personnel. Their function is to provide trend and data analysis to USAF customers worldwide on the performance of UPS batteries.
Future efforts will transition the responsibility of battery monitoring back to the PCCIE office. They will continue the monitoring program and increase the number of systems being monitored. The PCCIE office will also continue to research and identify monitoring systems that have potential of supporting the needs of the USAF.

TERMS

Cell: A cell is the smallest increment of a battery. Nominal voltage of 2.25 Vdc.
Jar or container: The smallest replaceable component in the battery string. Can be made up of one or more cells.
Battery: A SSUPS sees one battery, which is made up of multiple jars and cells.
Battery String: Series connected cells that equal the voltage of the DC link of an UPS. Multiple string is paralleled to increase battery run time.
Internal Resistance: The opposition to current flow in a cell.

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REFERENCES:

1. PCCIE Hand Book dated Jan 2000.
2. Exide Instructions for Installing and Operating Flooded Stationary Batteries Section 58.00.
3. B-TECH operation manuals.

AUTHORS:

Russell Hallett retired from the USAF with 20 years of experience as an Electrical Power Production Technician operating and maintaining electrical generators, supporting standby power systems, and prime power plants. He served 3 years on the PCCIE SMT maintaining UPS and battery systems for the USAF and conducted the PCCIE battery-monitoring program. Currently he is a Senior Instrumentation Technician with Applied Research Associates, Inc and a Scientific Engineering And Manpower Assistance Support (SEAMAS) contractor to the Air Force Research Laboratory and continues to monitor battery systems for the USAF. Tel: (850) 283-3881. Fax (850) 283-2035. E-mail: rhallett@ ara.com

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