WHEN THERMAL RUNAWAY STRIKES, WHAT SHOULD YOU DO?

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ABSTRACT

This paper is the documentary of a series of events from a data center, managed by my company for a State of California agency. This data center has four strings of large 2 volt VRLA cells that operate at a normal float voltage of 542 volts that back up parallel redundant 750 KW UPSs. The Data Center was opened in 1983 and these batteries were installed in June 2001, making them 8 years old when the thermal event occurred. The batteries are climate controlled, monitored, routinely maintained, and periodically load tested.

With the understanding that we are Data Center Facilities people and not "battery experts" we were forwarding our Cellcorder reports to a local outside battery maintenance organization for review with their more knowledgeable eyes. Yet even with these actions being taken, we still encountered an unexpected thermal run-away in one of the strings (P-2) with cell temperatures ranging from 180 – 200 degrees F.

This story of what occurred after that event, with actions taken that were contrary to the "predominant conventional wisdom and/or advice from our battery experts", turned out to be the right thing to do for this site. The actions taken were counter to the manufacturer's maintenance and operating instructions, yet so effective that it is amazing that more is not known about them.

INTRODUCTION

In 2007 we noticed that the cell resistance readings (taken with a Cellcorder) had increased substantially over the past 2 years. We contacted our battery service organization to give us an evaluation and they recommended that we perform Capacity Discharge Tests. We contracted them to monitor the batteries during the test which was run at the fully designed load of 600 KW. Talk about dismal results, as the UPS modules tripped in less than 16 seconds. Based upon those test results and recommendations, we requested quotes for replacement of the four battery strings. The lowest quote was $1.2 Million Dollars! The state was not going to spend that type of money, especially with the Governor's mandate to consolidate all Data Centers. Since our loads are substantially less than what the test was run at it was decided that we could safely ride thru an outage until our generators could start and take over the loads.

During our routine battery maintenance on June 10, 2009, we noticed that our P-2 battery string was very hot with cell temperatures between 95 and 110 degrees with an ambient of 75 degrees F. On June 11, 2009 a meeting was held that included personnel from site facilities, site management, the consultant company that designed the site, and the battery service organization, to decide on what actions needed to occur. Due to the understanding that this site was most likely not going to be in service for more than one more year, the idea of purchasing used batteries was even discussed. All options were open for discussion. What was well understood was that we had a problem and that no one knew the actual condition of our batteries, so it was decided to perform a load test on each system.

This time it was decided to run the load tests at a rate that would duplicate our actual loads, so that we could at least determine if we could indeed ride through a loss of utility power. The loads ranged from 280 to 285 KW. With this amount of load, these batteries should have been able to run for about 90 minutes. These tests that were run on June 20, 2009 and provided us with a "sort of" comfort level as the run times ranged from 21 to 35 minutes with P-2 at 21 minutes (Figure 1). These results showed us that the batteries would still allow us to safely transfer to our generators which take less than 60 seconds to start up, and take over the loads during a loss of utility power. However, the battery company's report recommended that we replace the batteries ASAP due to a statement that the IEEE 1188 Standard states that a battery that performs at less than 80% of its rating is increasing in its rate of deterioration (Figure 2).

This was about to become a very expensive unexpected expenditure on a site that was scheduled to be moving in less than one year's time. Try explaining this one to your management, and to your customer. How do you explain an unanticipated, unplanned, and unwanted capital expenditure, especially in these very difficult financial times?

Two days later on June 22, 2009 battery P-2 had cell temperatures from 180 – 200 degrees F. This battery was in a full blown thermal run away. To halt this event, we transferred the loads to our reserve modules and opened the battery disconnect to stop the charging current and to isolate that battery from the system. The following charts show the run times at load and the percentages of capacity for each of the battery strings during those load tests.

Figure 1 – As found run times under duplicated site loads.

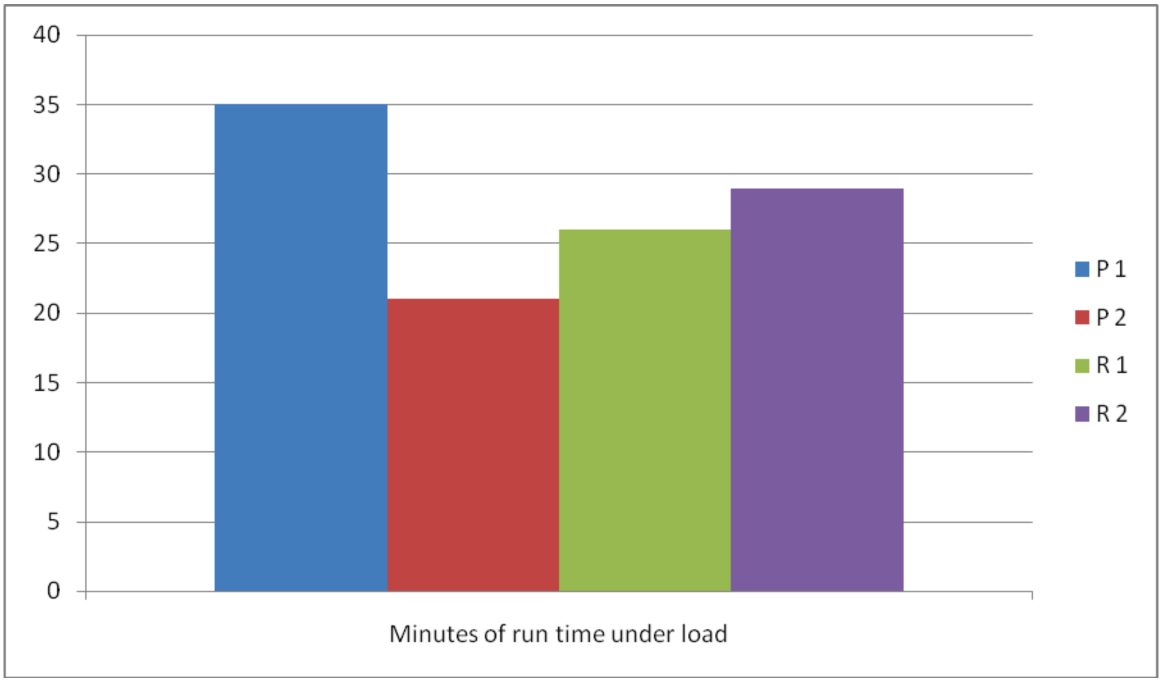
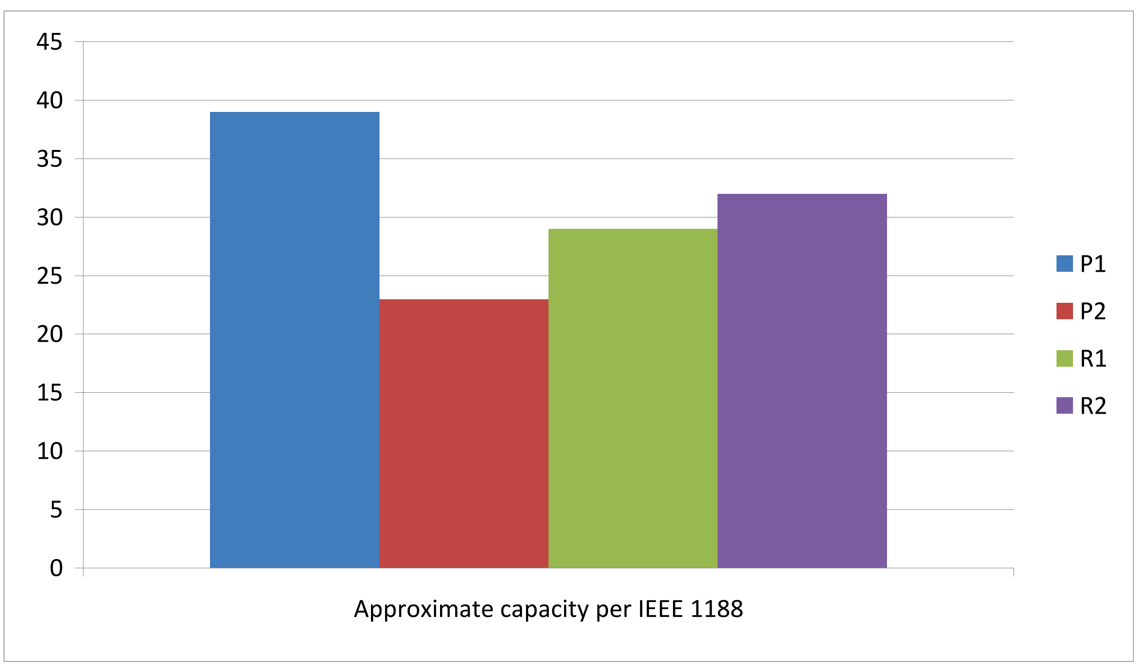


Figure 2 – Approximate capacity following IEEE 1188 Standard.



During discussions amongst the team that was involved in deciding what was needed to occur to protect our site, a representative from the firm that designed and started up this center brought up the idea of instead of replacing these batteries to look into a recovery process that his company was familiar with that was being used around the country that recovered batteries that had failed capacity tests, or that had gone into thermal runaway. Since we had never heard of such a thing, we decided to meet with the company and get educated on the process.

INVESTIGATION

During our initial contact, we were told that they had successfully performed the battery recovery process many times. They asked a lot of questions about our systems and requested copies of our maintenance and load test records for review, before they would make any commitments as to the recoverability of our battery systems with their process. Their explanation for their request for information was that they did not want to waste time on trying to recover something that could not be recovered. Following their review of the documentation we supplied, they came to the site to visually inspect the battery that went into thermal runaway and to make some spot checks with their own instrumentation on all of the battery strings. Following their site visit they reported on what they had observed and stated that they believed that they could make improvements to all four of the batteries, even the one that had been in thermal runaway. While they were on site they showed us that all four of the battery strings were drawing substantially more charge current than they should for their size and that there was a noticeable battery temperature spread above the ambient temperature. Their only exclusionary statement was that for their process to work the cell or cells must be structurally intact, and that they would not perform the process on cells that were not structurally intact, but that with all other cells and strings, they would make improvements plus would absolutely prevent the return of thermal runaway for the duration of the period that we were required to maintain this site. They were also willing to back up that guarantee.

We requested a list of companies with contact names and phone numbers where this process had been performed. Included in the list were users of batteries that ranged from 48 volt Telecom, thru 250 volt Power Generation, to 540 volt UPS systems just like our application. This process seems to work in all types of stationary applications. Each contact had nothing but words of praise for this process.

ACTIONS TAKEN

It was decided that the only prudent action to take was to contract the services of this company to perform their IOVR+™(1) process on our batteries. The fact that this was a “green” solution to our problem was indeed taken into consideration, as that factor should always be a consideration in any decision that might affect our environment. The process was a fraction of the cost to replace all the battery string cells.

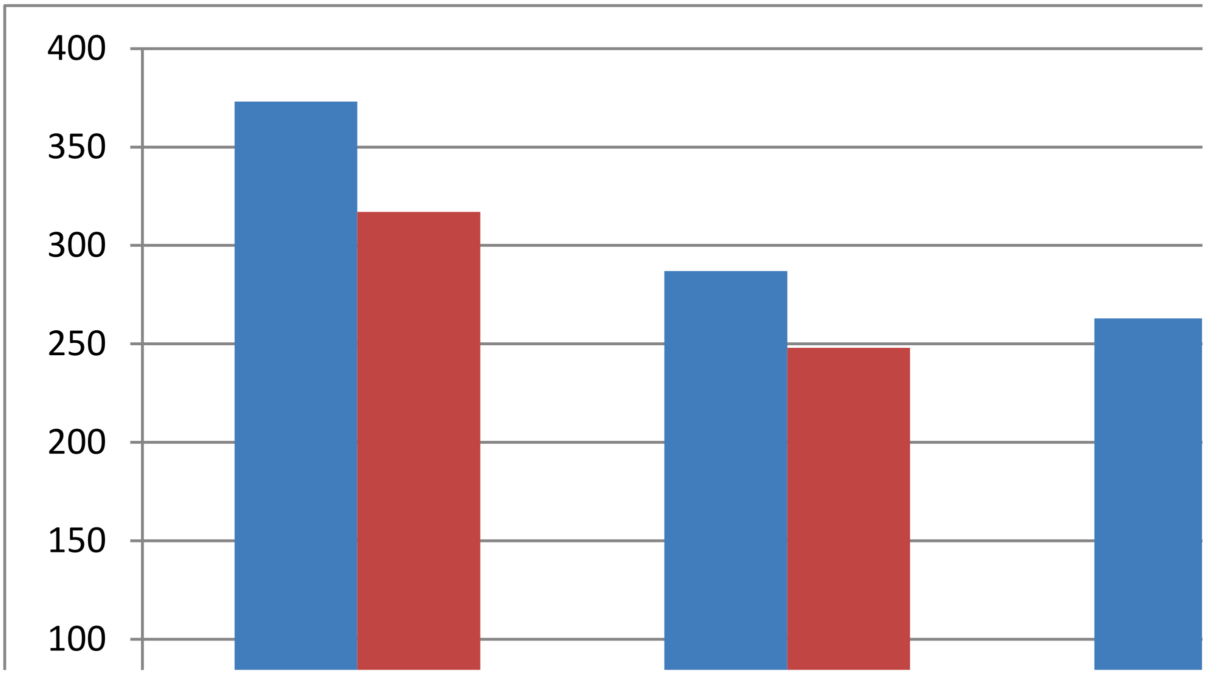
The team that performed the service was made up of three individuals, and required the string to be off line when they were working on making specific checks and the addition of water to each cell. While their exact steps were proprietary, it can be summed up in that after they determined the structurally integrity of each cell, they added varying amounts of water based upon the ohmic values that they measured prior to the structural integrity check. Then this was followed by a high rate charge, more measurements, some more water to individual cells “fine tuning” as they called it, more boost charging, then the installation of a catalyst in the head space. This work was performed during the first two weeks in August 2009.

The immediate results were that the ohmic values of the cells made a drastic improvement as can be seen from the before and after values in the following “Average Cell Resistances” chart. At the same time the float currents lowered substantially as can be seen in the “Float Current” chart. We of course were happy with these results as we did not want another thermal runaway, but awaited the follow up load test results to make our decision as to the success or failure of the project.

AVERAGE CELL RESISTANCES

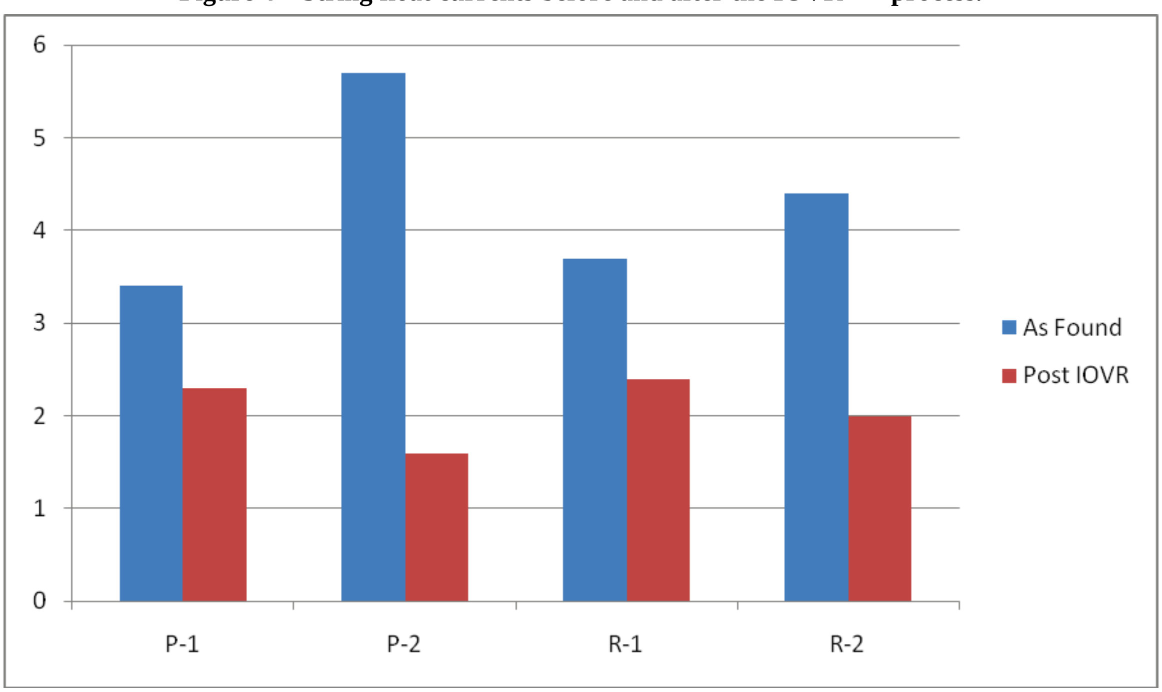
The following two charts show the before and after average cell resistances (Figure 3), and the before and after float current requirements (Figure 4).

Figure 3 – Pre and Post IOVR+™ process, average cell internal resistances.



FLOAT CURRENTS

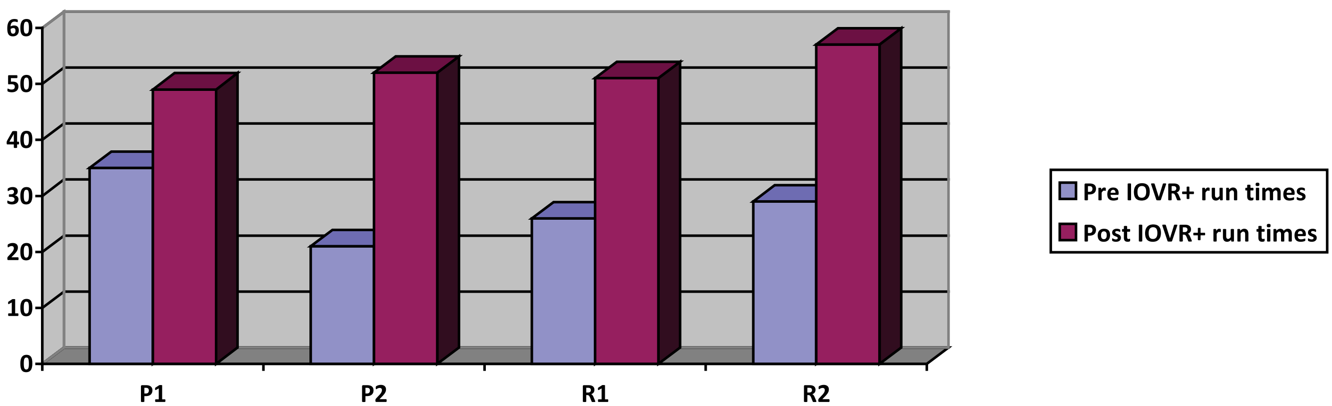
Figure 4 – String float currents before and after the IOVR+™ process.



FOLLOW UP LOAD TESTS

The chart below shows the (Pre IOVR+™) and post IOVR+™ process run time results. The discharge rates are identical in both the before and the after tests. The discharge load that was applied duplicated the loads that the site will actually see if off site power is lost. As explained previously the load tests that were run prior to the recovery process were all run on June 20, 2009. The follow up load tests on P-1, P-2, and R-2 were run on October 9, 2009 9Figure 5). R-1 was not tested at this time due to a system issue. We did however run a follow up load test on R-1 on January 22, 2010 (Figure 5). As can be seen in the following graph, all systems benefitted from the process with extended run times.

Figure 5 – difference in run times before and after the IOVR+™ process.



CONCLUSIONS

By utilizing this “green” solution we were able to reverse the effects of the thermal runaway situation, and restore these batteries that had been in full thermal runaway back to a useful and reliable battery string. In addition by utilizing this process we were able to be pro-active in preventing thermal runaway in our other three strings. And as an added benefit the recovery process recovered capacity and improved run time in all four strings, at a savings of almost $1,000,000.00. The facts that were able to reduce un-necessary capital expenditures and continue safe operation of the site was a real bonus.

Our results do however bring up the question of the applicability of the recommendations in the IEEE 1188 as to when is the proper time to replace a battery that fails a capacity test. Should it be replaced, or should corrective actions be attempted first, but that is a question that is beyond this presentation. It is easy to see that once the proper corrective actions were taken that there was not an increase in the decline of the battery, rather there was improvement.

Based upon our experience and discussions with the provider of the service, if we had performed this process on our battery strings earlier in their life, we would not have experienced such a decrease in capacity, nor would we have encountered a thermal runaway. It is clear to us now, that if we had understood what to actually be looking for that we would have observed the early warning signs of our impending failures and been able to avert them. Per their explanation there is always an increase in float current and a rise in cell temperatures over the ambient temperature well before any thermal event. We would suggest that anyone with this type of battery consider having the IOVR+™ process performed before they find themselves in this same type of situation.

REFERENCES

(1) IOVR+ is a registered trademark of Battery Research and Testing Inc. United States Patent and Trademark Serial No. 77/397,835. Canadian Intellectual Property Office, Trademark registration No. 3,239,431. European Union, OHIM-Office for Harmonization in the International Market, Trademarks and Designs, Trademark Registration # 006900492.