A LONG-TERM EVALUATION OF BATTERY MAINTENANCE/TESTING ACTIVITIES AT THE NEW YORK POWER AUTHORITY

William Cantor, P.E.
TPI
Shrewsbury, PA 17361

Daniel Levin, P.E.
New York Power Authority
White Plains, NY 10601

ABSTRACT

The New York Power Authority (NYPA) has many different maintenance locations. Prior to 1983, each area performed its own battery maintenance using slightly different procedures. Although NYPA was performing all of the maintenance to the best of its knowledge, there was some concern that all the procedures were not comprehensive. Load testing was not being performed.

Out of this concern, NYPA decided to use an outside independent contractor to perform battery testing. Every five years, or the first opportunity after a battery replacement, a performance test was completed. Around 1996, the testing portion was expanded to include a system test. The system test program incorporated testing of the charger/rectifier operation under full load conditions with the associated ac/dc distribution. Infrared thermography was utilized with system and battery testing. Additionally, the contractor was required to perform an annual battery inspection prior to all testing. The inspection included all of the requirements of IEEE 450[1].

For critical problems an urgent action report was issued immediately. A final report was generated that presented the results of the inspection and tests along with recommended corrective actions. Deficiencies in the existing maintenance program were also documented. A copy of the report was only sent to the maintenance supervisor of the respective location with an additional copy sent to the program administrator for quality control purposes.

In the 24 years since this program was conceived, there have not been any emergency situations where the batteries have failed in the entire NYPA system. This paper provides additional details of the program and discusses the financial benefits. In addition, sample test results are presented.

INTRODUCTION

The New York Power Authority has many different locations. Each location has its own management and maintenance organization. Most of the locations have between ten and twenty dc systems. The voltages of the dc systems range from 12 to 250 volts. The size of the batteries range from 100 ampere hours to 4000 ampere hours. The dc systems typically consist of a single battery and a single dc charger. However, most systems are co-located with a second system that can be tied together for redundancy and to facilitate maintenance activities.

The vast majority of batteries are lead acid flooded batteries located in semi-environmentally controlled conditions.

Prior to 1983, each location was completely responsible for maintaining its own dc systems. Each group was performing battery maintenance, but the process was not standardized. There was no load testing being performed. Since there were relatively few batteries per location, the dc system maintenance was a part-time activity for the electricians and little in-house battery expertise was developed.

In 1983, NYPA realized that a more comprehensive and consistent dc system maintenance approach was needed. Out of this concern, NYPA decided to use outside contractors to participate in dc systems maintenance and testing. The approach was initially two pronged.

First, the contractor was required to perform an annual battery inspection on every battery in the system. The inspection included all of the requirements of IEEE 450. A report was generated that presented both the results of the inspection along with recommended corrective actions. Deficiencies in the existing maintenance program were also documented. The copy of the report was sent to the maintenance supervisor of the respective location and an additional copy was sent to the program administrator for quality control purposes. Monthly and quarterly maintenance functions were continued by NYPA personnel.

Every five years, or the first opportunity after a battery replacement, a performance/acceptance test was completed. This was the test portion of the program and included all parts of the battery inspection plus load tests on the battery. Since there were less than 20 batteries tested annually, there was an economic advantage for NYPA to use an outside vendor over maintaining an in-house staff. Again these reports were given only to the maintenance supervisor and an additional copy was sent to the program administrator. Upon test completion a label was also affixed to the battery indicating the tested capacity and date of test.

This program fulfilled two major objectives. First, the program assisted greatly in bringing NYPA staff up to speed on all testing requirements and it also helped them standardize maintenance and testing procedures for all locations. Secondly, load tests were now being performed as recommended by IEEE 450 [1].

A further benefit of using a competent outside vendor is the added expertise. An outside vendor has exposure to many more dc systems. Additionally, the contractors used by NYPA have been active participants in the IEEE standards committee as well as industry conferences. These experiences have been used to assist NYPA with modern tools and techniques as well as to ensure that both the testing and NYPA in-house maintenance adheres to the latest standards.

After a few years of using the outside vendor for all maintenance and testing activities, NYPA re-evaluated the program and considered discontinuing the entire program in order to reduce costs. As part of this review NYPA realized that the periodic maintenance could be more efficiently performed by in-house personnel with support from the outside vendor as needed.

NYPA maintenance personnel were proficient at taking readings. Questionable readings were sent to the outside contractor for analysis as needed. The outside contractor continued to inspect all dc systems every five years and within a year of any new battery installation. The inspections conducted by the outside contractor were completed during the battery performance/acceptance test of the battery/system. The synergy of these two groups allowed NYPA to ensure that the dc systems were properly maintained.

The second major change was made several years into the program. Originally, the testing portion of the project concentrated on the battery only. However, the system reliability not only depends on the battery, but also requires that the charger and associated ac and dc distribution be capable of supporting an emergency condition. Therefore, the testing program was expanded to include the other portions of the dc system.

To accomplish the goal of testing the entire system, a systems test is performed prior to every battery test. During the systems test a dc load is placed in parallel with the system load. This load is slowly increased until the charger(s) goes into current limit. This stresses the charger and the associated ac and dc networks. Infrared thermography is utilized to scan these components while the system is under maximum load. Rectifier output is carefully measured and adjusted as needed, including float, equalize and current limits. Accuracy of charger meters is also verified and corrected if possible. Additionally, cable and ac/dc protection devices are also evaluated. Only after the system test has been validated will the battery testing portion begin. The additional costs associated with the systems testing are minimal because the equipment and personnel are already on-site for the battery testing.

FIELD TEST EXPERIENCES

Hundreds of tests have been performed over the life of the NYPA program. The testing regimen has identified numerous issues and has prevented untold failures. This paper will detail some of the representative issues that have been uncovered by this testing program.

The testing program has two main goals. The first goal is to identify and correct issues relating to the new installation of a dc system. The second goal is to determine the capability of existing dc systems and determine if the battery and/or charger system needs to be repaired or replaced. A main objective was to predict battery failure long before the situation became critical. This allowed NYPA to plan out their battery replacement purchases in the normal procurement cycle and prevented emergency unplanned battery purchases.

For flooded batteries, the failure of the battery can usually be predicted if the battery is tested on a regular basis. IEEE 450[1] recommends that the testing interval “should not be greater than 25% of the expected service life”. Considering that the expected service life of a flooded battery is approximately 20 years, a five year interval would be considered appropriate.

Many of the batteries in the NYPA system are designed for relatively high initial rates. For this reason, all tests are completed at the one hour rate.

In 1995, a nine year old flooded battery was tested and the capacity was found to be 85%. This capacity was lower than expected. Additionally, the ac ripple voltage was measured to be over 1 volt RMS. The ripple current was measured to be around 40 amps RMS. Both of these values are considered high. As part of the system test, an oscilloscope was used to measure and document the ripple voltage. This image is shown in Figure 1.

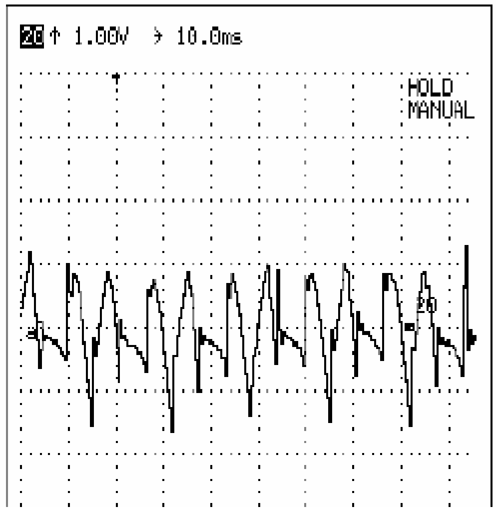

Figure 1 - Ripple Voltage

The battery performance was found to be 80% in 1999 when the battery was 13 years old. The battery was retested prior to the five year interval since the capacity of the previous test was below 90%. At this point, the battery was considered to be at the end of life and was recommended for replacement.

Although the battery was slated for replacement, the battery was not yet replaced in 2000 and the test was repeated. At this time the battery capacity had dropped to 67%. This demonstrated that the 80% point was clearly the knee of the life curve and the capacity started to drop rapidly from this point.

It was also observed in 2000 that the battery plates showed significant deterioration as can be seen in Figures 2 and 3.

Figure 2 – Excessive Sediment

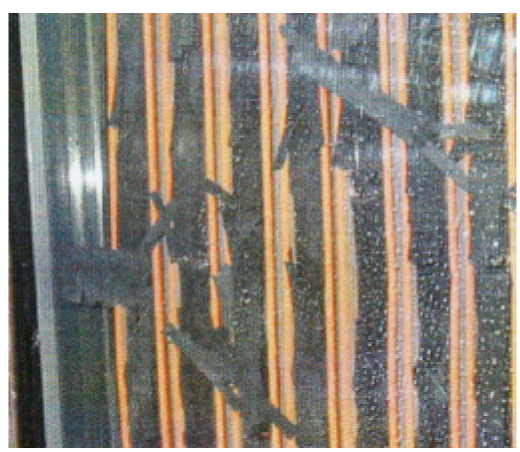

Figure 3 – Excessive Plate Deterioration

This example demonstrated that the end of life of a battery is predictable if periodic performance testing is completed and trended.

Another key part of the NYPA program is the use of infrared thermography. As previously mentioned, NYPA requires that the systems test be performed prior to the battery tests. The charger is loaded until the current limit point is reached. The load is monitored closely so that the battery is not discharged during this event. The load will be applied for a minimum of 20 minutes. Through experience, NYPA has determined that the vast majority of problems will be revealed within this twenty minute time window.

During the systems test, a high quality infrared thermography camera is utilized to scan the ac and dc network associated with the dc system. Any abnormal heating is investigated, analyzed and documented as needed. Recommendations, as appropriate, are offered by the contractor.

A typical problem is an abnormal connection on the dc or the ac network. Since the charger and the associated network are typically lightly loaded, a scan of the system under normal loads will probably not reveal poor connections.

Figures 4, 5 and 6 are representative of hot connections on ac and dc circuit breakers.

Figure 4 - Hot Leg - AC Circuit Breaker

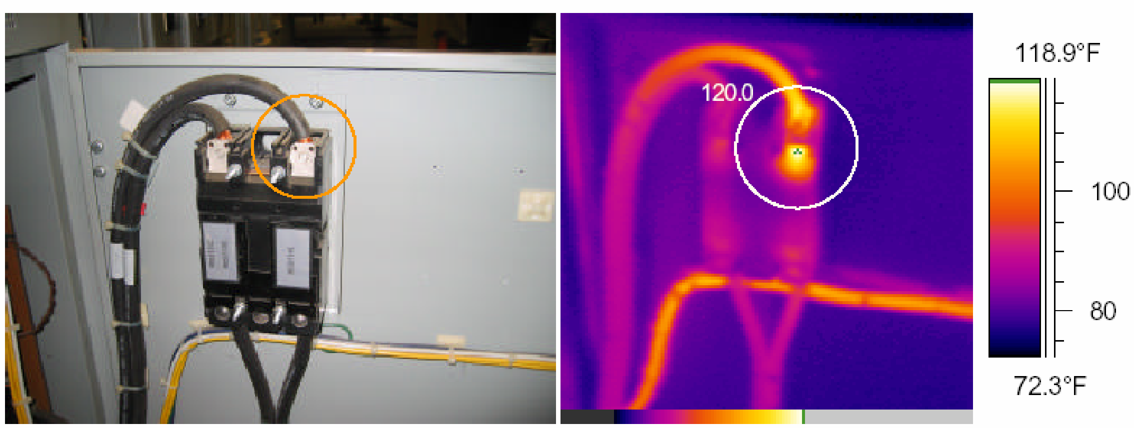

Figure 5 - Hot DC Breaker Connection

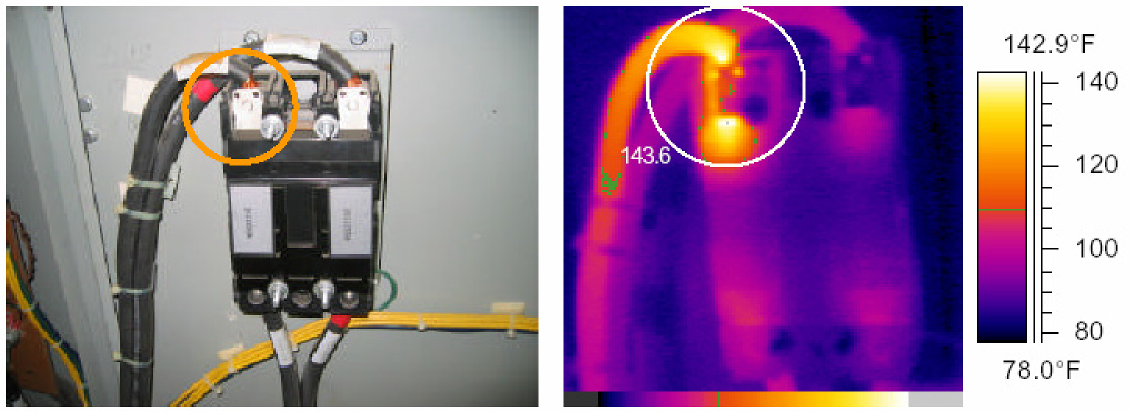

Figure 6 - Very Hot DC Breaker Connection

It is important to note that the above heating issues would not have been uncovered with infrared thermography under nominal loads. The full load condition is representative of a recharge event that would occur after a battery discharge. Additionally, a successful system test will ensure that the dc system will be capable of recharging the battery after the performance test.

Another important benefit gained from a maintenance and testing program is the elimination of finger pointing in the warranty claims process. An example of this is with two station batteries that were installed in 1993. During the acceptance test, the capacity was found to be lower than expected. The manufacturer was contacted at the time and initially the thought was that the capacity would rise over time. Subsequent tests proved this theory incorrect and in 2000, the battery failed the load test (See Figure 7).

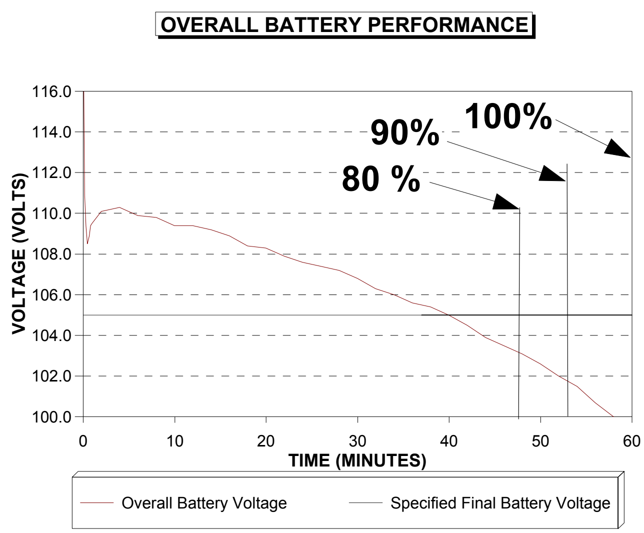

Figure 7 - Failed Battery - 7 year old station battery

Since the battery was faithfully tested and inspected throughout the life of the battery, the battery manufacturer did not dispute the finding and offered favorable warranty terms to NYPA to replace the battery.

For the most part, the battery warranties are not favorable to the user once the pro-rata portion of the warranty is reached. In many cases, the pro-rata portion of the warranty may be start after the first year. The warranty typically does not include de-installation, disposal, installation, shipping and acceptance costs. Additionally, most manufacturers are reluctant to grant warranty for batteries where the maintenance and test data is incomplete or non-existent. While some may feel this policy is unfair, the battery companies do have a legitimate concern about how the batteries were maintained. If the batteries were not maintained properly, the battery manufacturers are well justified to balk at providing compensation.

From a user perspective, it is important to maintain the batteries properly. It is just as important to document this maintenance and to alert the manufacturer as soon as there is a problem. If the problems can be identified prior to the pro-rata portion of the warranty, it is more likely that the total replacement costs can be covered by the manufacturer.

The on-site acceptance test is the most important action that the user can take. This test will not only verify the performance of the battery, but it will ensure that the battery was handled, stored, shipped, installed and initialized properly. A factory test only verifies the performance of the battery at the point of manufacture. Additionally, baseline data collected during the acceptance test is required for trending during the life of the battery.

The NYPA policy to perform the systems test at acceptance verifies the capability of the entire dc installation. Most problems found years after battery installation can be traced back to the initial installation. Loose connections, bad crimps, undersized cables and defective cells are just some of the items that usually can be pinpointed during an acceptance test but are usually found, if at all, years after the initial installation. The advantages of finding problems early are obvious. An added benefit is that the installation vendor and battery manufacturer are usually extremely accommodating with rectifying the problems during the acceptance phase of the project if the testing is done properly and fully documented.

The effect on ripple voltage and current has been discussed and debated over many years [2-6]. While some manufacturers state a maximum ripple value, others do not. It is more likely that the manufacturers will state a maximum ripple for their Valve Regulated Lead-Acid (VRLA) product line since it is generally accepted that these types of cells are more vulnerable to ripple.

However, based on the experience of NYPA, high ripple currents and voltages have shown to reduce the life expectancy of their batteries. As an example, the failed battery discussed earlier in the paper was thought to be degraded at least partially from the high ripple. In this case, as in many others, it is difficult to ascertain from the data whether or not the ripple was the cause of the failure since this was a field installation and not a test lab. The effects of ripple on batteries were investigated a few years ago [2, 5]. However, this work only went on for a year and did not investigate long term effects.

Fortunately, for comparison purposes, NYPA installed two identical batteries in two nearly identical dc systems. The two installations were in identical buildings which are within a few hundred yards of each other. The only difference was that one of the batteries was connected to a small UPS system and the other battery was not. The UPS system produced a significant amount of ripple (see Table 1). The batteries were tested multiple times and the results are shown in Table1. The battery plates at site N10 were found to be deteriorated in 2006 and the battery was not tested.

Table 1 - Effects of High Ripple

Site	AHr	AC ripple Volts	AC ripple Current	DC float current	Date of Manuf.	Initial Capacity	2001 Capacity	2006 Capacity
N10	577	480 mV	16 amps	0.2 amps	1995	115%	88%	Not tested
N9	577	160 mV	1.5 amps	0.27 amps	1995	115%	123%	125%

It is clear that the battery with the high ripple deteriorated quickly while the battery without the high ripple aged normally.

SUMMARY AND CONCLUSIONS

In the 24 years since the NYPA testing and maintenance program was initiated, there have not been any dc related issues that have effected the operation of any NYPA facility. As discussed earlier in this paper, there have been significant issues uncovered with the system and battery testing. However, each problem was detected in a controlled environment and did not affect the operation of the plant.

The reliability of the dc systems is not only attributable to the maintenance program, but is also greatly affected by the design and installation of the dc systems. NYPA has a detailed procurement standard for their batteries. The procurement process at NYPA is competitive and is typically based on the lowest cost. However, the procurement standard ensures that only quality batteries are purchased. Additionally, the maintenance contractor provides feedback to NYPA on the battery quality and the standard is constantly updated to ensure quality products.

NYPA has designed most of their dc systems to operate in pairs. Although each system typically operates independently, each pair of systems has a dc tie breaker that allows the two systems to be on a common dc bus. The two systems can be tied together and the battery of one of the systems can be safely removed allowing the other battery to provide a backup to both dc systems. This procedure can be used in an emergency situation as well as for maintenance and testing. A tagging process for tying the systems together is required by NYPA procedures for each pair of systems.

The above policy of tying systems together improves safety and significantly reduces costs. Without the tie breaker, a temporary battery would have to be utilized. Some of the batteries are as large as 4000 Ahr. These batteries are typically 125 volt (60 cell) systems. The cost would be prohibitive to provide an equivalent battery backup that would have similar reliability and connectivity (cables) to support some of the NYPA loads.

In addition, the tie breaker philosophy allows the testing to safely occur during normal operation of the plant which reduces the overall cost of the testing and support costs for NYPA personnel.

Most users would cite costs as the single most important reason as to why battery maintenance and or testing is not completed on their batteries. While most users would agree that maintenance and testing regimens would be desirable, the consensus is that the costs of a testing program would outweigh the benefits.

However, it is the opinion of NYPA that one major loss due to a battery failure would cost more than their total testing expenditures over the last 24 years. By only relying on a vendor for periodic (5 year) testing, the costs have been minimized.

NYPA did calculate the costs of performing the testing internally. While the maintenance activity may have been less expensive to perform internally, the costs associated with performing actual testing by NYPA personnel were higher than the costs being charged by the outside agency. Furthermore, with the added expertise of outside entity, the advantages of using an outside vendor were superior to keeping the work in house.

Using in-house personnel for routine readings is a key component of NYPA's program. In-house personnel ensure that there is local ownership of the systems while maintaining a level of in-house expertise. Personnel who maintain the batteries on a yearly basis are usually supervising the contractor during the testing phase of the program. This allows NYPA personnel to share information and to correlate their observations and readings with the performance of the battery. Abnormal readings and measurement techniques/equipment are also discussed between the contractor and the in-house personnel.

This paper is not intended to be an endorsement for the use of an outside contractor. This paper describes a simple, workable and cost effective maintenance and testing program for NYPA. Every organization needs to assess its own situation and level of expertise and consequently design a program that will work for them. As NYPA has proven, the program does not have to be complex and it can include a mix of in-house and contracted assets. It is key, however, to have expertise, whether local or contracted, who can analyze abnormal readings, stay current with tools and techniques and participate in industry forums.

For many organizations, taking readings and adding water is considered a maintenance program. However, in many cases, taking readings is a complete waste of time. If the readings are not analyzed, compared and trended, they are not worth the paper they are written on. Furthermore, testing has to be integral to any maintenance program. Testing is not a go/no-go endeavor. Testing is needed to trend battery performance. Trending gives users time to plan for battery replacement.

In conclusion, performing maintenance and testing in accordance with IEEE 450 is both effective and cost efficient. Individual organizations need to assess the advantages and disadvantages of using an outside organization. In the case of NYPA, a mix of internal and external resources was successful in minimizing costs, maximizing expertise and ensuring that the dc systems continued to provide the backup power needed. In the 24 years since the program was initiated, there has not been a single case where the dc systems have failed to provide power when needed.

Furthermore, the systems testing in conjunction with infrared thermography was important in detecting issues that were critical to the operation of the dc system. The incremental costs associated with the additional testing were minimal as compared to the total costs of the testing program.

REFERENCES

1. *IEEE recommended practice for maintenance, testing, and replacement of vented lead-acid batteries for stationary applications.* IEEE Std 450-2002, 2002.
2. Wilson, D. *The measurement of ripple current in battery plants*. in *Intelec 1998*. 1988.
3. Noworolski, Z. and U. Reskov. *AC, noise and migration in the battery installations*. in *Intelec*. 1996.
4. Nelson, R.F. and M.A. Kepros. *AC ripple effects on VRLA batteries in float applications*. in *Battery Conference on Applications and Advances, January 1999*. 1999.
5. Misra, S.S. *Stationary battery design and usage and its impact on life*. in *Intelec 1990*. 1990.
6. Harrison, A.I. *Batteries and AC phenomena in UPS systems: the battery point of view*. in *Intelec*. 1989.