Are Your UPS System Batteries Really Ready to Load Test?

A White Paper by Liebert

SUMMARY
In a critical power application, stationary batteries should be properly installed, inspected, commissioned and tested before being placed into full service. Unfortunately, some installers hurry through inspections and the load test is performed before the batteries are properly prepared. This paper outlines the correct way to prepare batteries for load test and explains the importance of each step.

How important are these procedures?
Specifications for large UPS systems frequently say, “Successful bidder shall provide full load rated battery testing.” This is a good requirement. After all, the batteries are expected to provide a specified amount of backup power, so it makes sense to verify actual installed capacity. However, many of these same specifications do *not* require an IEEE-based battery certification in advance of the load test. This leads to the question: Is it prudent to perform a 100% load test on a battery system that has not been fully inspected and tested?

Sometimes it seems hard to justify spending extra time and money troubleshooting your new battery plant *before* testing (“Hey, won’t the load test itself will reveal any problems?”). Any number of “real-world” factors can pressure you to cut corners in order to recover lost time:

- Batteries are long-lead items, and were among the last major components delivered to the site.
- Contractor delays kept you from finishing the battery installation until just yesterday.
- The UPS and switchgear are already in place and have passed preliminary functional testing.
- The IS manager is anxious to get conditioned power to his new data center.
- The project is already behind schedule and all the vendors want to get paid.

The pressures may be severe, but stand firm in your commitment to pre-testing and inspection. Your new room full of batteries is a complex electrochemical system with hundreds of jars and interconnects mounted on custom-assembled racks. Anything can go wrong. On a more positive note, proper inspection and testing will give you useful information that can be applied immediately and which will serve as a baseline for testing throughout the service life of the batteries.

What will I learn and why is that important?
In a critical power system, knowing and understanding the condition of a stationary battery is important. Inspection and testing will reveal:

- Interconnection integrity
- State of charge
- The overall correctness of the installation
- Benchmark values for comparison to results of future tests, and

- Data to aid troubleshooting when performance is less than designed or anticipated.

If basic information is not collected, analyzed and understood before initial charging and dynamic testing, the results are unpredictable. There is a very real possibility that the battery could suffer damage if a major problem is not diagnosed in advance. Some possible consequences are:

- Terminal failure due to loose connections
- Reduced capacity due to incomplete state of charge
- Damaged cells due to incorrect polarity orientation
- High connection resistance due to incorrectly prepared mating surfaces
- Schedule delays and extra costs to replace or repair damaged items.

A properly performed certification inspection, therefore, is very important, whether or not the specification requires it.

How Should A Certification Inspection Be Conducted?
The procedures, processes and methods discussed here focus on the vented lead acid stationary battery installed on racks. We will not study testing for the smaller valve-regulated lead acid (VRLA) batteries normally installed in cabinets.

Battery system installation certification inspections can be performed by the installing contractor, by a third-party battery service provider or by the battery manufacturer's authorized representatives. The completed inspection report should be available to those responsible for the battery and thoroughly reviewed. Any necessary corrective action as a result of the inspection should be carried out *before* the battery receives its initial charge.

A certification inspection is performed in three phases:

- Mechanical inspection
- Pre-charge electrical inspection
- Electrochemical-chemical inspection prior to load testing

Mechanical Inspection
These steps should be carried out *prior to* initial charging.

1. Check all rack hardware for tightness. This is best accomplished before racks are loaded with cells. Missing hardware should be replaced *before* racks are loaded. *Never* loosen hardware on a loaded rack -- it may collapse.

2. Inspect the battery for general cleanliness. The battery should be free of spilled electrolyte, construction debris, heavy dirt and excessive dust. Heavily soiled battery systems should be cleaned before being placed in service.

3. Inspect the rack rails and jar undersides for chemical residue. The author has observed increasing numbers of installing contractors using various compounds to lubricate the tops of the rails. This practice makes it easier to slide jars along the rails. Unfortunately, not all compounds react benignly with jar materials. Most oil-based products -- even those as mild as cooking spray -- react with jar materials. In one well-publicized case, a contractor used cable-pulling grease on the frame rails; within weeks, virtually all the jars were leaking. The first sign of such a reaction is the cracking and crazing of the plastic jar material. Generally, once a reaction is observed, the cell must be replaced. To avoid this situation, installers must be familiar with the battery makers' recommendations and use

only compounds approved or recommended by them. To be on the safe side, many manufacturers recommend using plain water; it provides some amount of lubrication and evaporates afterward without leaving an oily residue.

4. All jars and covers should be examined for cracks and leaks. Leaking cells should be replaced at the earliest possible time. Leaking cells quickly contaminate racks. This can cause ground fault alarms to trip and present a safety hazard to service personnel.

5. All flame arrestors should be intact and installed securely. Batteries should never be charged unless all flame arrestors are properly installed. VRLA battery pressure relief valves should be in place and secure as well. The perimeter of the vent well and flame arrestor seal ring should be clean and dry before flame arrestors are installed. This will prevent electrolyte migration from inside the cell to outside the gasket area.

6. Check all inter-tier, inter-rack and inter-aisle connecting cables for excessive stress on terminals, as evidenced by twisting and "leaning" of posts and terminals. Cable must not cause stress to these components. Corrective action is necessary when stress is observed.

7. A corrosion inhibiting compound is generally supplied with a battery and should be applied per manufacturer instructions."No-Oxide A" grease is commonly used, although some manufacturers specify the use of other similar compounds. The primary function of these compounds is to seal the critical contact area from oxygen exposure, thereby slowing the corrosion process. This can increase the time intervals between costly system interconnection reworks. Proper contact surface preparation is very important.

Pre-Charge Electrical Inspection

After the mechanical inspection is complete and prior to charging the battery, the following steps should be performed:

1. Verify that all cells are arranged in the proper series connection. A common installation error is interconnecting cells with like polarities.

2. Check all bolted interconnections for tightness to the proper value per manufacturer specifications. Errors we have observed include; (a) an incorrect torque setting and (b) a wrench graduated in foot pounds instead of the more common inch-pounds unit ofmeasure.

3. Establish a connection resistance benchmark. This is very important. We recommend that your technicians disassemble, clean and remake several inter-cell connections at random. This will verify the effectiveness of the preparation method used by installation personnel. Average the sum of the readings of the specimen connections and use that value as the system benchmark. IEEE 484-1987[1] recommends a 10% allowable upward deviation from the average. For example, a system whose inter-cell connection average value is 40µ ohms can tolerate a maximum of 44µ ohms. Reworking the connection usually reduces an out-of-tolerance resistance. This procedure should be conducted for inter-tier, inter-rack and inter-aisle cable connections also. Only connections of the same geometry can be compared to one another.

4. After a resistance benchmark has been established, measure and record *all* interconnection resistances. Reference the readings to the benchmark standards and make note of any connections requiring corrective action based on the acceptance criteria from line 3 above.

5. Measure and record total battery voltage at the open circuit potential. Divide that reading by number of cells in the string. The resulting per-cell value should be close to the calculated open circuit voltage. Refer to Table 1 in Appendix A.

If the tasks above have been completed and meet the acceptance criteria, initial charging of the battery may then begin. Items that do not conform to the battery manufacturer or IEEE standards *must* be noted on the inspection report and corrected. Corrective action should be taken as soon as practical. The amount of time a battery requires to reach a fully charged state for testing is a function of several conditions:

- Applied charging voltage
- Ambient temperature
- Battery state of charge prior to commissioning, and
- Physical size of the cells.

The commissioning charge, also referred to as a freshening or initial charge, should be determined based on the requirements and tolerances of both battery and the equipment to which it is connected. Determine the required applied voltage by multiplying the number of cells by the per-cell charge recommendations in the battery manufacturer operating instructions. This value must not exceed the charging system capability.

Electro-Chemical Pre-Testing
In Pre-Test, the following tasks should always be completed prior to load testing the battery system:

1. Before load tests can take place, the battery must be fully charged. and the state of charge must verified. This cannot be overemphasized. Generally, a battery is considered to be fully charged when the voltage of lowest cell in the string stops rising over three consecutive hourly readings while on equalize charge and the lowest specific gravity measurement is within the nominal rating by a window of +/- 10 (.010) gravity points. This can be used as a guideline during charging. Refer to the battery manufacturer’s specific instructions for more detail.

2. Find the lowest cell and verify the state of charge as described above. If the cell voltage continues to rise with the next hourly reading, continue the equalize charge until it stops rising. When that cell voltage stops rising, the battery should then be returned to normal float status. Monitor cell temperature while on charge. Do not exceed the maximum allowable temperature or cells may be damaged.

3. IEEE 450-1995 states a battery should receive an equalize charge and be returned to normal float potential *for no less than 3 days, but not longer than 30 days* prior to testing. This three-day period will allow time for all the hydrogen gas bubbles (formed on the plates during equalize charging) to be released from the surface of the plates. Until all the bubbles are released, the full surface area of the plates is not available for chemical interaction with the electrolyte, and the battery could appear to have diminished capacity.

4. When Items 2 and 3 are satisfied, measure and record the specific gravity of each cell in the battery just prior to the load test. If the gravity readings are within the manufacturer’s recommended window, (usually +/- 10 points), they are considered acceptable. For specific details regarding allowable gravity values, refer to the battery manufacturer installation and operating instructions.

5. Measure and record the electrolyte temperature of every sixth cell, with not less than 10% of the total number of cells in the battery. Battery performance data is referenced to 77 degrees, F. (25 C). Cooler temperatures will cause diminished battery capacity. Higher temperatures will cause increased capacity, but reduce service life. Temperature considerations are a frequently neglected factor in the load testing equation.

Correcting for Temperature
If the cell temperature is other than 77 degrees F, some amount of compensation should be factored into the load test procedure. Unless the purchase specification called for a different operating temperature, the UPS battery was sized by the manufacturerfor operation at 77 degrees F. Therefore battery performance will be diminished at cooler temperatures and artificially increased at higher temperatures. The simplest way to compensate for temperature is to increase or decrease the kW setting of the load bank and then testing to see if the batteries achieve the originally specified backup time.

Correction factors are listed in Table 2 in Appendix A. To illustrate their use, let's take a sample UPS system rated at 750 kVA and 600 kW (Rated kW), and assume the cell electrolyte temperature was measured at 67°F. Table 2 shows a temperature correction factor (Tc) of 1.064. Load bank setting (AC kW) can be expressed by the formula:

$$AC\ kW = (Rated\ kW)/Tc$$

$$AC\ kW = (600\ kW)/1.064$$

$$AC\ kW = 564\ kW$$

The original 77 degree AC KW would have been 600 KW. The corrected load bank setting indicates a difference of 36 KW (6% of rated capacity). Had the battery been tested at the full 600 kW load, the battery would have provided less than rated backup time.

Summary
It is critical to ensure battery system integrity *before* it is load tested. It must be fully charged, properly installed and its condition verified in order to minimize the likelihood of retests and equipment damage. When compared with the cost of downtime, delays, retests and hardware failures, the cost of battery certification is a bargain, well worth the expense and time added to a project.

Appendix A: Data Tables

Rated Gravity	OCV
1.170	2.010
1.215	2.055
1.225	2.065
1.250	2.090
1.275	2.115
1.300	2.140

Table 1. Specific Gravity Ratings and Open Circuit Voltage (.840 + Specific Gravity.)

Cell Temperature		Correction	Cell Temperature		Correction
Degrees C	Degrees F	Factor (Tc)	Degrees C	Degrees F	Factor (Tc)
-3.9	25	1.520	25.6	78	0.994
-1.1	30	1.430	26.1	79	0.987
1.7	35	1.350	26.7	80	0.980
4.4	40	1.300	27.2	81	0.976
7.2	45	1.250	27.8	82	0.972
10.0	50	1.190	28.3	83	0.968
12.8	55	1.150	28.9	84	0.964
15.6	60	1.110	29.4	85	0.960
18.3	65	1.080	30.0	86	0.956
18.9	66	1.072	30.6	87	0.952
19.4	67	1.064	31.1	88	0.948

20.0	68	1.056	31.6	89	0.944
20.6	69	1.048	32.2	90	0.940
21.1	70	1.040	35.0	95	0.930
21.7	71	1.034	37.8	100	0.910
22.2	72	1.029	40.6	105	0.890
22.8	73	1.023	43.3	110	0.880
23.4	74	1.017	46.1	115	0.870
23.9	75	1.011	48.9	120	0.860
24.5	76	1.006	51.7	125	0.850
25.0	**77**	**1.000**			

Table 2 - Temperature Correction Factors for Lead Acid Batteries

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[1]IEEE 484-1987 "IEEE Recommended Practice for Installation Design and Installation of Large Lead Storage Batteries for Generating Stations and Substations"