APPLICATION NOTE

Six essentials tests to keep your UPS system running

Critical facilities such as data centers, hospitals, airports and utilities have to be available 100 % of the time. As more and more organizations move workloads and transaction processing into the cloud, data centers become even more critical because typically it's not just one organization they serve—it could be hundreds. If there's a power outage, there's no room for downtime. The transition to backup power has to be seamless and instantaneous.

To achieve that, data centers typically back up their critical systems with uninterruptible power supplies (UPS). The UPS systems are always on, ready to deliver the necessary power instantly in the event of an outage until the auxiliary generator kicks in.

Regularly testing individual battery cells as well as the UPS system as a whole is critical to both reliability and getting the most life out of your batteries as possible. If a single battery in a string fails, it affects not only that battery but the entire string. If a single cell is open, the entire string of batteries will go offline, leaving critical loads unsupported. A single bad battery can drastically affect the usable life of adjacent batteries by raising their charge voltage.

When asked what happens if a UPS system fails, one DC Operations Manager noted, "That never can happen if I want to keep my job. The UPS system is our lifeline for connecting to our generators in the event of a utility outage. If they don't work, the customers go down and that's unacceptable."

Top 5 causes of battery failure

- Loose terminals and intercell connections
- Aging batteries
- Over-charging and over-discharging
- Thermal runaway which causes excessive heat
- Ripple

Five key UPS battery health tests

Using a battery analyzer you can determine the overall health of UPS batteries by measuring:

- Voltage of individual cells
- The voltage drop across each cable
- AC ripple voltage and frequency
- Float voltage and current
- Cell temperature

Four key indicators of battery failure

When conducting battery tests, look for these indicators of failure:

- More than a 10 % drop in capacity compared to the baseline or previous measurement
- A 20 % or more increase in strap resistance compared to baseline or previous measurement
- Sustained high temperatures compared to baseline and manufacturer's specs
- Degradation in plate condition

The care and feeding of a healthy data center UPS system

To ensure your UPS systems are ready to take over at any moment, data centers run comprehensive battery maintenance programs to ensure maximum reliability and help prevent deterioration. These include a series of regular inspections—monthly, quarterly and annually based on the criticality of the components—in addition to continuous monitoring and alarm systems.

Although most batteries used in today's UPS systems are "maintenance free" they are still subject to deterioration from corrosion, internal shorts, sulphation, dry-out, and seal failure. This application note outlines best practices for keeping these battery banks at optimum performance, so that if an outage does occur, it is invisible to that facility's customers. The recommendations in this document are based on both the TIA-942 Standard for data centers and the IEEE Standard 1188™–2005 Recommended Practice for Maintenance, Testing, and Replacement of Valve-Regulated Lead-Acid (VRLA) Batteries for Stationary Applications.

What to test and when

The Institute of Electronic and Electrical Engineers (IEEE) is the primary source of standard practices for battery maintenance. The IEEE recommends performing the following tests on a regular basis, over the life of the battery to be able to better predict when to replace it. Be sure to wear the proper personal protective equipment (PPE) before performing any of these tests.

	Voltage and current			Temperature		Ohmic		Ripple
Items	**Overall float voltage measured at the battery terminals**	**Charger output current and voltage**	**DC float current (per string)**	**Ambient temperature**	**Temperature of the negative terminal of each cell**	**Cell/unit internal ohmic values**	**Cell-to-cell and terminal connection detail resistance of entire battery AC ripple current and/or voltage imposed on the battery**	**AC ripple current and/or voltage imposed on the battery**
Monthly	•	•	•	•				
Quarterly	•	•	•	•	•	•		
Yearly and Initial	•	•	•	•	•	•	•	•

Internal battery and intercell strap resistance testing

Measuring internal ohmic values—internal resistance—is a key indicator of how much life is left in your batteries. Battery resistance stays relatively flat up to the point when the battery approaches its end of life. A battery with a high level of internal resistance can overheat and ignite during discharge. Voltage measurements alone will not flag this danger. Regularly measuring and tracking internal resistance can help you identify a battery that needs replacing.

The best way to measure internal battery resistance is with a specialized battery tester like the Fluke BT521 Advanced Battery Analyzer that allows you to measure battery resistance while the battery is in service. The BT521 measures the impedance (internal resistance) of the battery by injecting an AC current signal. You should also measure the resistance of the intercell "strap" connection between batteries in a string. The resulting ohmic values of these tests will give you a good assessment of the health of your batteries.

Remember, a single ohmic measurement is of little value on its own. Best practice requires measuring internal resistance over months and years, each time comparing it to the initial baseline reading. A 30 % to 50 % increase in resistance compared to the baseline is a strong indicator that your battery is on the road to failure and should be replaced soon.

Discharge testing

Healthy batteries should maintain a capacity above 90 % of the manufacturer's rating. Most manufacturers recommend replacing the battery if its capacity falls below 80 %. Discharge testing is the ultimate way to discover the true available capacity of a battery. To perform this test, connect the battery to a load and discharge it over a specified period of time. During this test period, current is regulated and a constant known current is drawn, while voltage is measured at regular intervals. Details of the discharge current, the specified time period for discharge testing, and the capacity of the battery in ampere hours can be calculated and compared to the manufacturers' specification.

Batteries cannot support critical loads during and immediately after a discharge test so you should transfer critical loads to a different battery bank until well after the test is complete. Then reconnect a temporary, comparably-sized load to the batteries under test. In addition, before conducting the discharge test, prepare a cooling system to compensate for a rise in ambient temperature. When large batteries discharge, they release a significant amount of energy as heat.

The IEEE recommends the following schedule for discharge testing:

- An acceptance test made at the manufacturer's factory or upon initial installation
- Periodic discharge testing at an interval not greater than 25 % of the expected service life, or two years, whichever is less
- Annual discharge testing when any battery has reached 85 % of the expected service life or dropped more than 10 % in capacity

Since scheduling full scale discharge testing can be difficult, good regular maintenance is extremely important. Operating the battery according to manufacturer charging requirements and following the IEEE recommendations for battery testing, will help maximize the life of the battery system.

Ripple voltage testing

Ripple is unwanted residual AC component from the rectified voltage that is converted to DC in the charging process. Some chargers in UPS systems do not have filters that remove ripple components so higher levels of ripple are applied to the battery. This can cause batteries to deteriorate before their time. AC ripple on the charger output should be minimized.

You can check the charger's DC output using a battery analyzer or ScopeMeter® Test Tool with an appropriate DC current clamp meter. Measure the output voltage at the charger output terminals on a monthly basis. Ripple testing should be performed annually.

Float voltage and float current testing

Float voltage is the voltage level at which a battery is maintained after being fully charged. Float current describes the current that is continuously applied to the battery to keep it fully charged. The amount of the float current is based on the size of the battery but that value should stay constant. An increase in float current could result in thermal runaway, which occurs when an increase in temperature in a battery changes the condition of the battery. Those changes cause further temperature increases, which can eventually destroy the battery.

To measure float voltage, measure the voltage of an individual cell or a battery string after it has been fully charged, using a battery analyzer such as a Fluke BT521.

To measure DC float current, refer to the manufacturer's specifications for approximate values for expected float currents. Use an appropriate DC current clamp meter such as an Amprobe LH41A to measure expected float current. Both float voltage and float current tests should be conducted monthly.

Additional UPS component testing and maintenance

In addition to testing the batteries, technicians need to test other components of the UPS system to ensure that the batteries stay properly charged and there is a seamless transition from the normal power source to the bypass power source.

UPS transferring/switching time

By industry standards, power supply units inside IT equipment are designed to store enough energy to keep the device running for about 20 milliseconds (ms) of power interruption. This is known as "hold-up time." That means the device can withstand brief interruptions in power while a UPS transitions between modes of operation, such as from normal operation mode to battery and back again. However, transfer time should actually be much faster than 20 ms, because the longer the PSU (power supply unit for computer) goes without power, the larger the inrush current it draws when it receives power again. Inrush could exceed the current handling capacity of the UPS and cause it to shut down. A portable oscilloscope like Fluke 190II is capable of high-speed sampling (2.5–5G/s), multi-channel waveform monitoring and recording simultaneously to accurately capture the switching time.

Typical UPS type	Suggested switching time
Standby	5–12 ms
Line-interactive	3–8 ms (5 ms typical)
Double-conversion	Zero interruption
Delta-conversion	Zero interruption

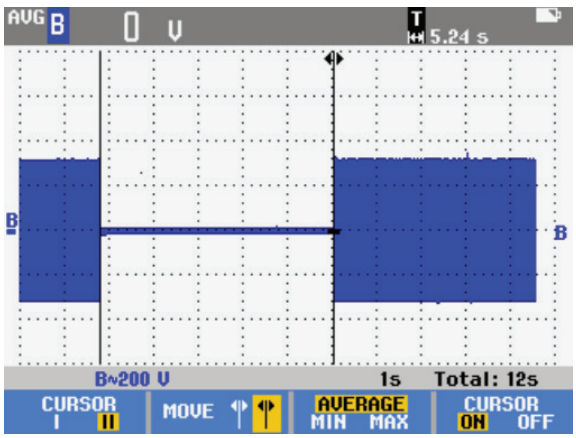

Figure 1: Results of a switching test showing the switch failed.

Input and output power inspection

Power quality is also critical to ensuring that the AC power used to charge the battery is clean and the DC output from the battery is adequate to power the data center until the generator takes over. Using a Fluke ScopeMeter 190 II series or a power quality analyzer, technicians need to measure phase balance and frequency to look for harmonics, noise, and spikes. ScopeMeter Test Tools present multiple parameters simultaneously to provide a comprehensive view of power quality under various test scenarios. This can help them visually correlate any potential problems on the output of a rectifier circuit to the input.

Fluke 500 Series Battery Analyzers at a glance

Fluke 500 Series Battery Analyzers were designed from the ground up to match IEEE recommendations for maintenance, troubleshooting and performance testing of individual stationary batteries and battery banks used in UPS systems for critical facilities such as data centers

Reporting and asset management with The Fluke Battery Management Desktop Software

The BT521 will make building reports and keeping track of measurements simple. Using the Fluke Battery Management Desktop Software, users can download test results from the Battery Analyzer for report generation and analysis. Create details in the report by adding comments, photos, and supplementary information for the report. Measurement data can be exported to Excel® for further processing.

The graphical presentations of battery sequence make testing for analysis intuitive. See the histogram of batter string with user defined threshold.

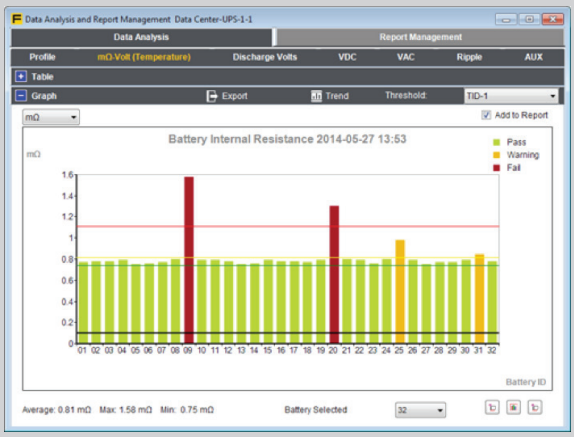

Figure 2: A histogram of battery string with a user defined threshold.

The measurement data and battery profile information is stored and archived with the Management Software and can be used compare results, switch results between conductance and resistance readings and perform trend analysis. See the historical trend of data of batteries below.

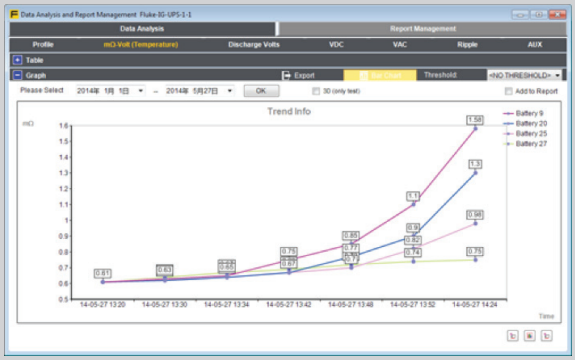

Figure 3: Historical trend data of batteries.

All measurement data, battery profile and analysis information can be used to easily generate reports and archive for later comparison of data.

Fluke 500 Series Battery Analyzers at a glance (continued)

Key features

When conducting battery tests, look for these indicators of failure:

- **Internal resistance testing:** Measures the impedance (internal resistance) of the battery by injecting an AC current signal.
- **Discharge testing:** Collects the voltage of each battery multiple times at a user-defined interval during a discharge or load test. Users can calculate the time a battery takes to drop to the cut-off voltage and use this time to determine the capacity loss of the battery.
- **Ripple voltage testing:** Allows users to test AC components in DC charging circuits.
- **Sequence modes and meter:** Sequence mode allows you to retest a battery and manage battery strings. Meter mode allows you to read and save a measurement or time sequence, during a quick test or troubleshooting.
- **Threshold and warning:** Allows you to configure a maximum of 10 sets of thresholds and receive a pass/warning/fail indication after each measurement.
- **AutoHold:** Captures readings that remain stable for 1 second and then releases the reading when a new measurement starts.
- **AutoSave:** Automatically saves AutoHold-captured readings to internal memory.
- **Fluke Battery Management Desktop Software:** For importing, storing, comparing, trending and charting data and meaningfully displaying that information in reports.
- **Fluke Battery Analyze mobile app:** wireless communication for data download and remote display while measuring via mobile app.
- **Highest safety rating in the industry:** CAT III 600 V, 1000 V dc max. rated for safe measurements all around the battery power supply equipment

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