WHITE PAPER

canara

Sudden Impedance Rise (SIR)

The common cause of Stationary Battery related UPS failures

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BACKGROUND

A catastrophic power failure has just occurred; the Facilities Manager is explaining to the CIO "why" the data center power failed when the UPS was supposed to work.

FM: The UPS manufacturer found an "Open Battery".

CIO: What in the world is an Open Battery?

FM: Well, the UPS has 40 batteries connected together in a string. Each Battery has 6 cells and if one cell "opens", it fails and the string is broken much like old series wired Christmas tree lights, and the UPS fails.

CIO: When were the batteries checked last?

FM: About 6 weeks ago, we performed quarterly maintenance. Everything checked out. These batteries are only 3 years old. This shouldn't have happened!

CIO: This outage will take a week to recover from and cost more than $1,000,000. What do we tell the CFO?

ABSTRACT

Sudden Impedance Rise (SIR) in a Stationary Battery is indicated by an exponential rise of internal resistance over a period of 2–4 weeks. SIR, which can occur at anytime in the serviceable life of a battery, is a common form of battery failure. A SIR battery (if not replaced) will open, jeopardizing the integrity and reliability of the UPS. In the worst case, a failed open cell can even explode under load conditions, jeopardizing safety.

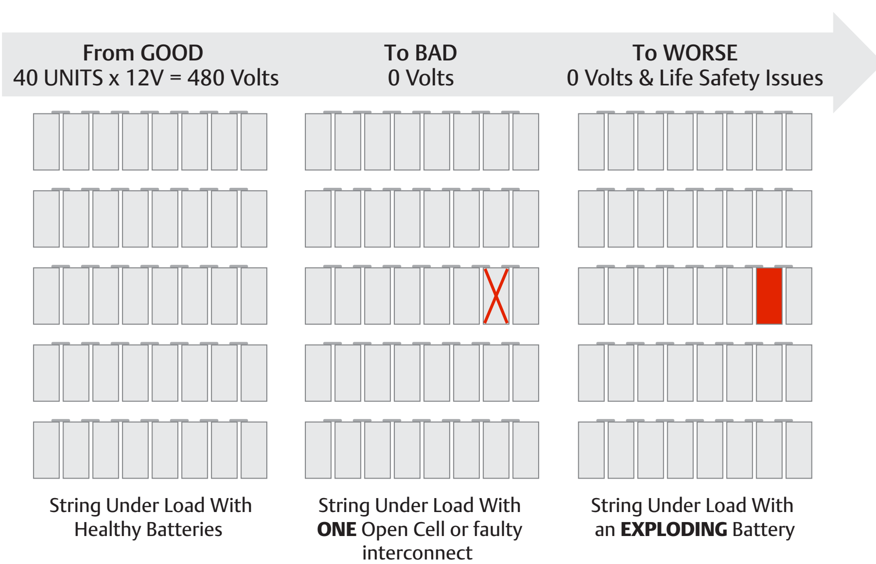

Figure 1: Only one open cell can cause a string to fail

Importance of a robust battery maintenance / monitoring program

Best Practice battery maintenance/inspection and monitoring on stationary batteries requires two key elements.

1) Quarterly maintenance and inspection, and

2) A weekly monitoring program (at a minimum)

The reliability of any UPS system will be impaired if either program is compromised or omitted. Maintenance and inspection programs must require personnel:

• To ensure proper torque of external connections

• To discover signs of battery swelling, electrolyte leakage, corrosion and/or bacterial growth, etc.

• To provide a crosscheck and review of monitoring data

Weekly monitoring or more often provides predictive failure analysis by trending:

• Unit internal and battery interconnection resistance (ohmic value)

• Unit/string voltage

• Battery internal temperature

• Ambient temperature

• AC ripple

• UPS discharge data

This paper focuses on one element/benefit of weekly or more often monitoring in preventing SIR related power outages.

Canara Recommended Practices

Canara recommends that stationary batteries should be investigated when the battery monitoring system indicates an ohmic rise of 15% (maintenance threshold) of the initial ohmic values and replaced when they exceed 20% (replacement threshold) of the initial ohmic values.

The decision to replace a battery should always be independently confirmed by conducting a unit level performance capacity test. Never perform a capacity test on any battery that is suspected of being open or shorted. The discharge test should be conducted by qualified personnel as per the manufacturer's specification for pass/fail criteria.

Basing measurements on the delta between the initial ohmic value and the current ohmic value is a critical element of string life. The initial ohmic value of a battery can vary from the manufacturer's specification by up to 20% with no observed affect in battery life or performance. Therefore a battery specified with an internal ohmic value of 2.25mΩ can have an initial range from 2.3-2.7mΩ. The replacement threshold can vary from 2.875-3.375mΩ.

Note: Changes in temperature and/or changes in test equipment, impact measured values significantly. Always ensure that the same, calibrated testing device is used through the life of a given battery.

Replacing batteries at an artificial "standard" threshold can be costly. Replacing batteries prematurely in a string impacts the life of the string. One key criterion for string replacement is that the string be replaced when 25% (maximum) of the batteries have been replaced. As a battery ages, the internal ohmic value normally rises. Each new battery introduced into a string has a lower impedance/resistance than the surrounding batteries due to their age. Introduce enough new batteries into the string and the string can become imbalanced, overcharging some batteries while undercharging others, accelerating the aging of the entire string.

TREND GRAPHS

The first three cases below are all from the same string of batteries installed at a well-designed and well-operated Tier III datacenter of a major financial institution. This string and the redundant system at this site have been less eventful as the strings matured.

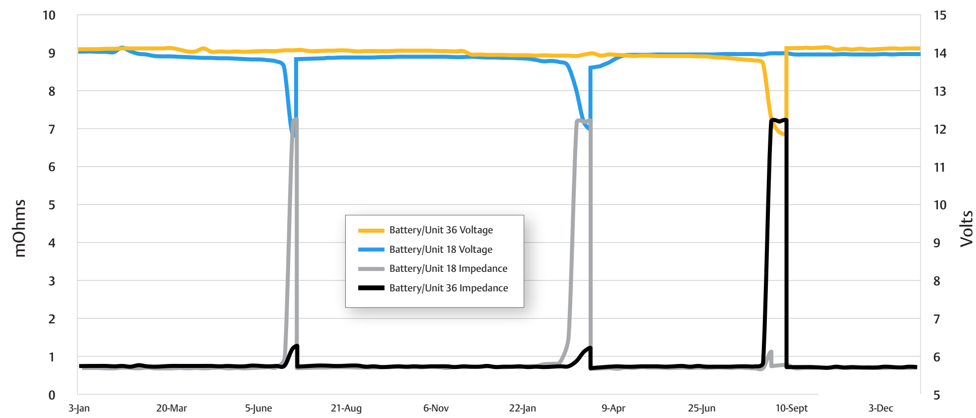

Chart 1: 3 cases of sudden impedance rise from a single datacenter

Consider the following cases for two units from the same string of batteries.

Case 1: Risk of Spot Checks

Chart 2 shows a flooded battery with an initial ohmic value of 0.67mΩ. The maintenance threshold on this battery would be 0.77mΩ and the replacement threshold would be 0.8mΩ. This battery was installed in December and trended normally until late May 22. A "Spot Test" associated with quarterly maintenance on June 19 would have shown this battery to be within acceptable standards, the voltage level may have called for a recommendation to equalize the string.

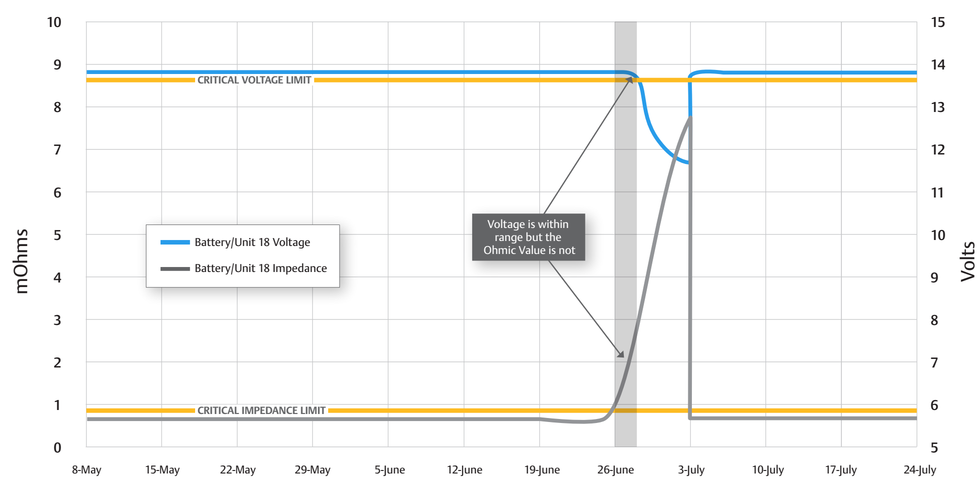

Chart 2: Battery/Unit 18: a flooded battery showing a sudden impedance/resistance rise

Takeaway

SIR is clearly indicated from June 26 to July 10 and the battery was replaced by July 17. The Voltage Trend demonstrates a corresponding fall in voltage sometimes associated with the rise in impedance/resistance.

Case 2: Early Mortality

Chart 3 shows a flooded battery with an initial impedance/resistance of 0.69mΩ. The maintenance threshold on this battery would be 0.79mΩ and the replacement threshold would be 0.83mΩ. This battery was installed in July replacing the battery in Chart 2 and trended normally until late February.

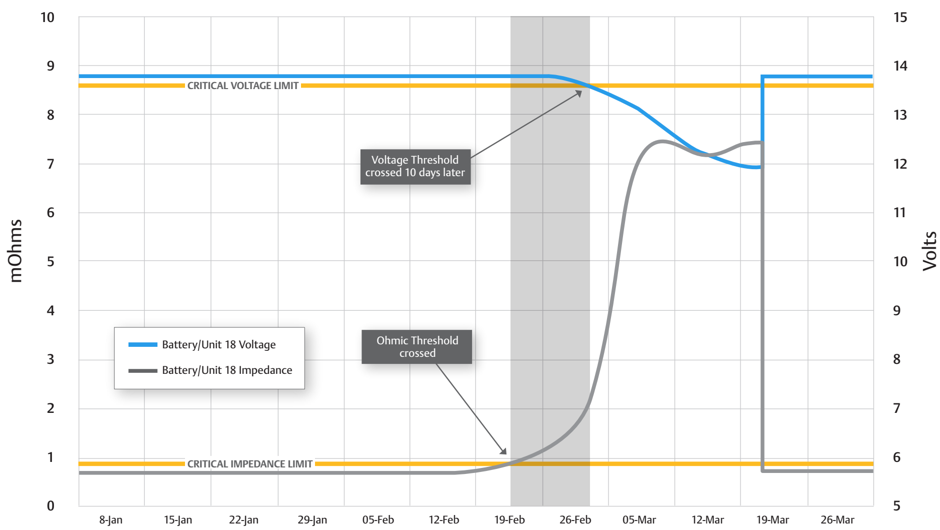

Chart 3: Battery/Unit 18 was replaced in early July and failed in only 7 months, again showing SIR

Takeaway

This case could be considered infant mortality as the battery replaced in Case 1 above failed in only 7 months. By monitoring and storing the key vital signs, this battery was replaced under warranty, and a potential outage was avoided.

Case 3: Failure within 3 years

Chart 4 shows a flooded battery with an initial impedance/resistance of 0.69mΩ. The maintenance threshold on this battery would be 0.79mΩ and the replacement threshold would be 0.83mΩ. This battery was installed in December and trended normally until late August.

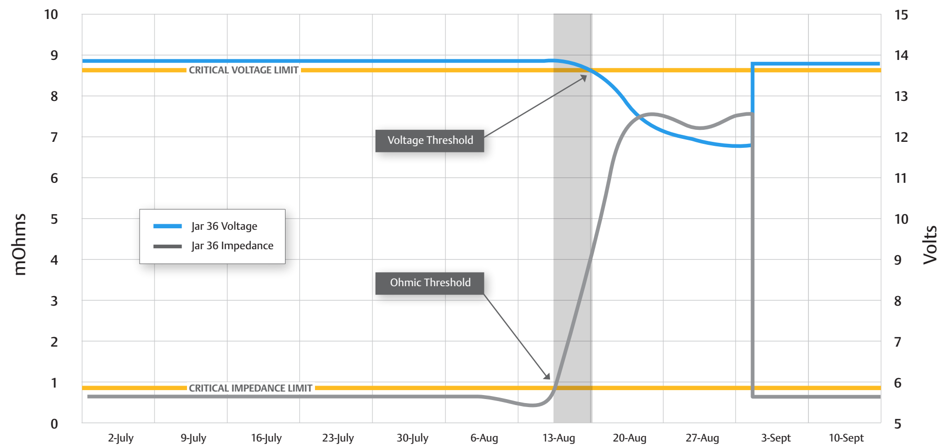

Chart 4: The impedance rise provides earlier insight into the battery

Chart 4 illustrates how the output of a UPS system is a regenerated AC sine wave derived from a square wave (filtered). The Insulated Gate Bipolar Transistors (IGBT) turn on and off reproducing the sine wave. AC capacitors smooth out the sine wave.

Takeaway

Like Case 2, this battery was replaced under warranty, and a potential outage was avoided.

Case 4: Predicting failure in a timely manner

Chart 5 shows a VRLA battery with an initial ohmic value of 2.5mΩ. The maintenance threshold on this battery would be 3.0mΩ and the replacement threshold would be 3.125mΩ. This battery was installed in August and trended normally until late November.

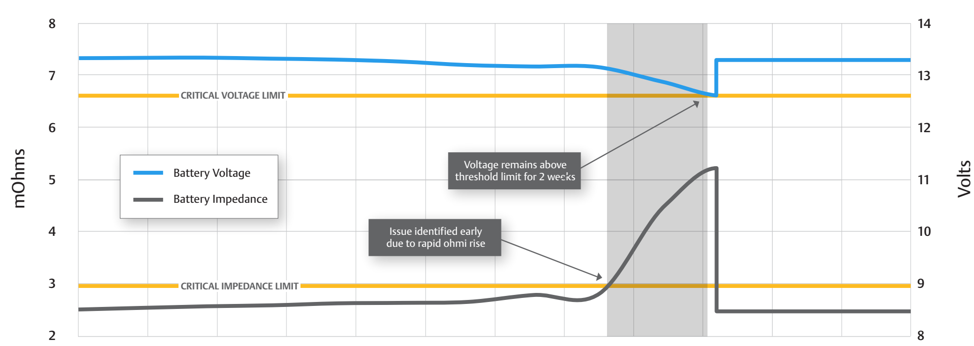

Chart 5: SIR indicates imminent battery failure

Takeaway

The Voltage Trend demonstrates a corresponding fall in voltage sometimes associated with the rise in ohmic value. Also note that the replacement battery was not fully charged at the time of installation. This new battery was installed in an undercharged condition and took 8 weeks to equalize with the string.

Case 5: Voltage Remains within Limits

Chart 6 shows a VRLA battery with an initial impedance/resistance of 2.4mΩ. The maintenance threshold on this battery would be 2.88mΩ and the replacement threshold would be 3.0mΩ. This battery was installed in February and trended normally until late July.

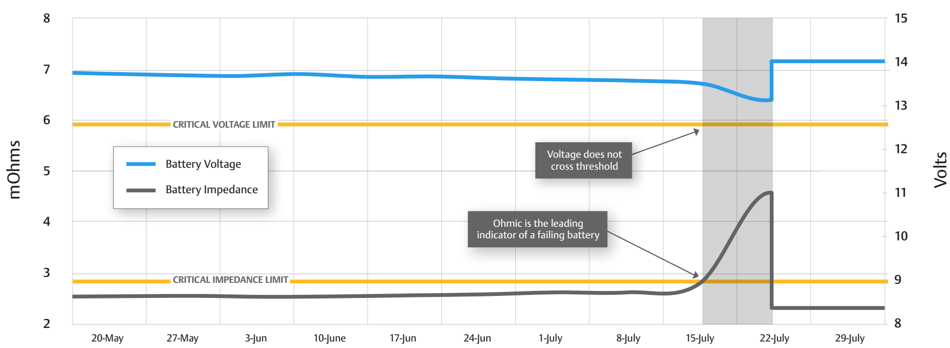

Chart 6: Voltage drops but remains within limits, where Ohmic surpasses threshold quickly

Takeaway

SIR in this case occurred in just 2 weeks and the battery was replaced immediately. The Voltage Trend again demonstrates a corresponding fall in voltage sometimes associated with the rise in impedance/resistance but remains within limits. Voltage is the lagging indicator in up to 30% of battery failures. In this case the new battery was overcharged at the time of installation and remained above 2.27 volts per cell for 6 weeks. Float voltages exceeding 2.27 volts per cell will reduce battery life.

CONCLUSION

Power outages caused by SIR batteries are 100% preventable. However, a minimum of weekly, preferably daily, battery-monitoring program is required to prevent SIR related power outages. SIR is a major problem in the industry in both flooded and VRLA batteries. Unfortunately many data center operators are not aware of the risk of SIR. Canara has heard similar conversations to that of the Facilities Manager, CIO, and CFO, from prospective customers after SIR outages.

These graphs are just a few from hundreds of examples of SIR collected over the past 20 years by Canara. Canara currently monitors close to 300,000 batteries globally and has a database with over 1.5 billion data points on trended battery performance. Each day or week, voltage and impedance/resistance readings are polled by our servers and analyzed. Trends are identified using a combination of analysis by monitoring software and manual data analysis. When a trend develops customers are notified, and the failing batteries are replaced reducing the risk of an outage.

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