Applying Conductance Technology to Enhance the Reliability of Power Systems

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The provisioning of back-up power systems or uninterruptible power supplies (UPS) is often a "last line of defense" for Facility, Maintenance, or Operations Managers to ensure business continuity. Oftentimes, these systems are installed and placed "on-line" without much thought or consideration placed on the fact that most system options include battery systems as the primary means for storage of electrical energy. Because of the growth of communications systems, electronic commerce opportunities, and an "information on demand" culture, more and more UPS systems, and therefore stationary batteries have been deployed in ever increasing numbers by a wide variety of organizations.

This increasing population of batteries has created a tremendous need for effective training, methods and tools to ensure that battery performance, and thereby system performance meets the designed requirements. This growth, as well as the introduction of a wide number of variables (including environmental fluctuations, application variations, and design inconsistencies), has generated a demand for more advanced, effective and efficient approaches to ensure continued reliability from stationary batteries. Most organizations that rely on stationary batteries for back-up power recognize that proper consistent, and effective testing or monitoring of the stationary batteries within the systems (including detailed testing to the individual battery cell level) is essential for effective system cost management and power assurance.

As a result of this, battery testing has become a necessary element of a power maintenance regime. In the past, this routine has included regular battery discharge (also known as load or rundown) testing. This testing, while quite conclusive in terms of evaluating the battery systems' ability to deliver its designed power *at that given moment*, can be somewhat impractical for modern operations given the logistics, time and resources required (not to mention the expertise and safety precautions). To address these weaknesses, electronic test technology (with roots and a proven history back to the 1970s) has been enhanced with cutting edge electronics to offer an effective alternative to the burdensome qualities of battery discharge testing. A leader among this electronic technology has been the measurement of electrical conductance to determine the battery's ability to deliver power.

Using Conductance Technology to Effectively Assess Battery Performance

Battery conductance is a measurement of a battery's ability to produce current/power. It is calculated and measured through the injection of an AC signal of known value, and capturing the conducted output. The resultant output is then analyzed and produces a numeric value that has been designated as either Siemens or Mhos (the reverse of Ohms, the measure of resistance rather than conductance). The value in conductance or other Ohmic measurements can be more directly described as: *An increased internal resistance or reduced measured conductance of a cell results in a reduction of the expected capacity or discharge performance from the cell.*[2] Conductance can be also described as the equivalent measurement/approximation of the plate and reaction sites/surface available within the battery for chemical reaction and exchange, a known determinant of the limits of supplied power from the battery. During the normal aging and use process, the battery's plate surface can sulfate, shed active material, and change chemically; conversions that adversely affect the battery's ability to perform. This regular aging/degradation process forces battery conductance to decrease gradually as the cell service life is consumed, and therefore an intuitive trending pattern can be established. This premise supports evidence demonstrating that battery state-of-health can be identified when comparing conductance measurements from similar cells in a battery system. The higher a registered conductance value (or lower internal resistance), the more healthy the battery and therefore better performance can be anticipated.

To validate these points and the effectiveness of these techniques as tools to evaluate battery performance capabilities, conductance testing, along with the other Ohmic techniques, has been examined extensively in independent laboratory research.[3] The data in Figures A and B illustrate that the conductance technique (when applied correctly with an optimized AC signal injection frequency) has a dependable capability in identifying the suspect cells:

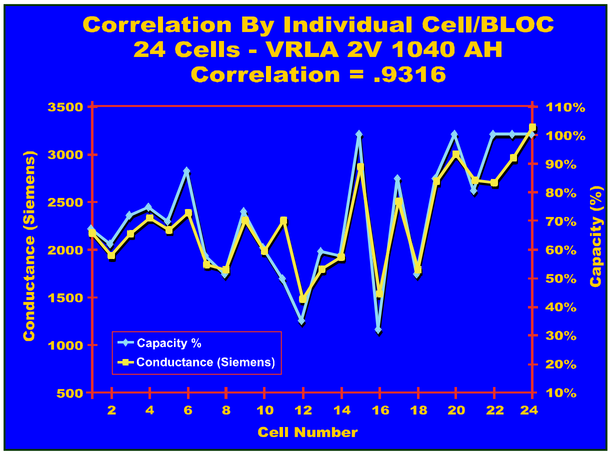

Figure A.

Figure B.

With respect to power provisioning, this implies that conductance can be used to detect cell defects, degradation and other variables that can adversely impact the ability of the battery to deliver current or produce power. Conductance test measurements can, therefore, become an equivalent screening method capable of suggesting the battery's true state-of-health diagnosis.

Due to these characteristics, it is then concluded that conductance can provide significant assistance in preventing catastrophic system failures that can not only eliminate the "insurance" benefit promised by the UPS system, but can also create dangerous scenarios for personnel, equipment and other assets. By implementation of a consistent program of testing of the entire string of batteries (as well as intercell connections, hardware, electronics and other elements) in a stationary power system, gross deviations among batteries or the system can be are easily identified and corrective actions can be instituted prior to the system being called into service or a serious event occurring.

To further illustrate this point, the following example is offered: if a particular battery (monobloc or cell) produces a conductance measurement of 150 Siemens, while the remainder of the batteries within the same string measure at an average of 2200 Siemens, the technician can be assured that the cell has experienced a significant loss of capacity and that performance of the overall system is compromised. The battery, and therefore the system, cannot be expected to perform to its designed level, providing the power levels expected and supporting the equipment (potentially mission critical) load. Perhaps more significant, this type of deviation from the remainder of the units suggests that there does exist a potential for danger should the system be called into service and a sizeable load placed on it. Through the introduction of regular conductance testing, this type of battery fault can be identified prior to a failure, without a discharge or disruption in power, and without removing the equipment from service. Corrective actions can be scheduled under non-emergency conditions, improving the quality of response, eliminating risk and significantly reducing costs.

Regular Assessment of Battery Health and Development of Replacement Strategies

An associated benefit from regular system maintenance and more accurately battery conductance testing is simply to promote increased service life, and, perhaps more important from a management standpoint, ensure full use of the consumable service life. By monitoring and testing a battery site through the deployment of conductance enabled equipment, warning signs of unacceptable operating conditions can be detected and rectified prior to a catastrophic loss. By making necessary corrections to the power system, battery life can be extended and replacement costs reduced or avoided entirely.

Another benefit of Conductance monitoring and testing is the ability predict end-of-life for battery cells and strings. Rather than just identifying degraded cells, Conductance testing can be used to measure battery health over time. By regularly measuring conductance from the time of installation, changes in measured conductance and the related loss of capacity can be observed and trended. The rate of degradation can be estimated from this practice, allowing effective management of time for replacement and procurement of the consumable element of the power system.

To further support these suggestions, it is also prudent to mention that the current battery maintenance practices developed and endorsed by the IEEE advise Ohmic testing of all Valve-regulated, lead acid batteries once per quarter. It is suggested that this testing will allow for effective maintenance and assurance of the performance of the system. However, this concept is based on understanding the capacity, or conductance, for a new, healthy battery. By using the measured conductance value of an "optimized" cell or the average conductance signature of a battery type sampling as a benchmark, an operator can easily develop a replacement strategy as conductance degrades over time and apply the maintenance methodology adopted by many organizations who have successfully reduced battery related failures and unnecessary costs.

Enhanced, Yet Simplified Battery Management

While there are many benefits offered by the use of Ohmic testing technology, and specifically Conductance testing, simplified management of the battery system is perhaps the most significant. Through the application of conductance technology into a battery management product or system, simplicity of use, portability and functionality are uniquely included through well thought-out menu configuration, data logging capacity, portable printing options, PC data transfer, and trending software reducing documentation and administration requirements. Battery suppliers, test equipment developers and large user groups are working to collect a library of benchmark reference values for common batteries to further help streamline the overall maintenance complexity. As a result, there is a reduction in the "guesswork" of battery management, and ability for companies to reduce their battery replacement costs by scheduled replacement of only necessary batteries.

To further understand the proliferation in the implementation of Ohmic, and more accurately conductance, testing programs it is important to analyze its attributes compared to discharge testing:

* <u>Fast</u>: The most obvious attribute of a conductance test as compared to a discharge test (or, in fact, some other Ohmic tests) is speed. Conductance tests produce measurements in a matter of seconds rather than the hours of time required for discharge testing and the subsequent data collection and report development. With some equipment, test results (including printed reports and data files) can be available in *just seconds*, rather than after several hours of battery discharge. Conductance technology also enables battery monitoring that is full time, on-line, and automated -- eliminating costly labor and travel to remote locations.

* <u>On-Line Testing</u>: Traditional battery load or discharge testing, when done correctly often involves several hours of power system and technician down time. Furthermore, in some scenarios, the apparatus being supported can be made unavailable while it is offline and the battery system could be compromised for over 24 hours depending on certain factors including safety issues, load equipment, re-cabling, and battery discharge and recharge time. The latest conductance technology monitors or tests battery power systems on-line without any system disruption or downtime and these tests are passive and do not alter or cycle the battery to cause premature aging.

* <u>Accurate</u>: At the same time, Conductance testing has proven accurate to the level that even a few global telecom companies (and industry where often stringent standards have been set for system reliability and availability) have discontinued discharge testing, except to completely analyze a questionable battery cell with a low conductance value. (See *Figures A & B* for correlation statistics.)

* <u>Safety issues:</u> The passive nature of the latest Conductance technology makes it substantially safer than discharge testing. A full discharge test can produce heat and often sparks through the extraction of large amounts of electrical energy from the battery system, and these components can be dangerous to operator/technician, sensitive electronic equipment and the overall site. In comparison, testers and monitors utilizing conductance technology generate no measurable energy exchange eliminating the potentially hazardous circumstanced posed by heat, produced hydrogen gas and electrical arcing during the load testing process.

* <u>Repeatable</u>: One coincidental benefit of passive conductance testing is that measurements are fully repeatable, verifying suspect results. Cells can be tested at any time without waiting for a recharge and with no safety risk or degradation of the system. This can also be executed to meet spot inspection or site validation requirements including testing inter-cell connection resistance values.

* Simple: In addition to being quick, Ohmic testing can also be very simple. Removing the guesswork of battery interpretation is only the start. The newest conductance testers are menu-driven, require only pinpoint connection to two battery posts or straps, and provide absolute measurements with no further mathematical calculations needed.

Finally, one of the best aspects associated with Ohmic/Conductance technology advances is that the equipment is relatively inexpensive when compared to older technologies, both from a capital investment standpoint as well as the aforementioned savings in time. These savings in resources and improved safety aspects alone make this technology an affordable and desirable service option positioned to become a standard tool of technicians in a variety of industries and applications where stationary battery systems are relied upon. This proliferation will further expand the user and knowledge base, extending technological innovation and resulting in more benefits associated with Ohmic testing.

References

[1-3] Cox, Daniel C., *Establishing VRLA Battery Maintenance Programs Using Ohmic Reference Values and Historical Test Data*