Voltage-Slope Method Reserve Time Accuracy

Aspects of a simple algorithm for computing reserve time during discharge were discussed in the 2018 Battcon paper "Time (Only) Referenced Rundown Test." Specifically, the paper presented an example of the voltage-slope technique explained as method 1 in US Patent 6,211,654 by Thomas D. O'Sullivan. This follow-up paper examines the accuracy of these predictions made using the voltage-slope technique. Predictions and actual results are compared using discharge data supplied by a battery manufacturer. Predictions against battery curve table estimates are also examined. In addition, the paper examines how the method 2 division factors effect of the accuracy of the result (e.g. an End Voltage of 1.75 VDC requires a division factor of 2). Variables such as depth of discharge and slope-width (time duration) will also be considered. Lastly, this paper demonstrates how the method 3 calibration works and improves predictions.

P2685 – A new IEEE recommended practice for Sizing, Installation, Maintenance, Testing, and Replacement of Starting Batteries for Electric Power Generation Sets

A standby power system consists of many components. While stationary batteries are usually critical to the system, they are typically an interim power source while generation sets (generators) pick up the load for the long run. At many critical installations, if the generators do not start, the site will be in severe jeopardy. The weakest link in the starting of generators, and possibly the weakest link in the entire standby system is the generator starting battery (or other generator starting energy storage device). Unfortunately, the generator starting battery has not been the focus of most designers/installers/maintainers in the design and operation of critical backup power systems. Many times, the applicable codes and standards are misunderstood or misapplied and additional cost and downtime are often realized by end-users because of the lack of guidance with these energy storage devices. This new IEEE document is to provide selection, design, installation, maintenance and replacement guidelines and recommendations for generator starting batteries as well as other applicable generator starting energy storage devices. This paper will provide an outline of the proposed document as well as some select content with the intention of soliciting input from and ideas from all interested and affected parties.

DC Systems in High Voltage Transmission Stations

The DC System in a high voltage transmission station is one of the most important part of the system. It acts as a back-up during loss of AC supply to critical elements of the system. Many regulatory bodies such as NERC, NPCC etc. are dictating maintenance planning on the protection and DC system components. The cost of maintaining the DC system is going higher day by day with extra requirements from regulators. This paper presents Hydro One's DC system demographics, how they maintain it and why they are we thinking of going to online monitoring. Currently most of the maintenance is done manually and time based which has its own benefits and consequences vs. online monitors. Online monitoring solutions are really attractive but it comes with a cost. The question arises that is it worth the investment? What is Hydro One doing to be compliant, where is the company now in terms of implementing online monitoring? And what does the company expect after installation of online monitoring. DC system online monitoring has its own pros and cons as described in the paper but it would be up to the proof of concept project to determine the real value of online monitoring.

More Than Just Convenience: A Life Study Case for Front Access VRLA Batteries

For practical reasons, many traditional 12V VRLA batteries look much like car batteries. 2V cells are arranged in series in a 1x6 configuration with the positive and negative terminals on opposite sides of the cover (top terminal). In recent years, the stand-by power industry has seen an influx of "front-access" 12V batteries, monoblocs with a 2x3 cell configuration, with the terminals located in close proximity on the narrow side of the battery. Safety, ease of maintenance, and convenient cabinet footprint are some of the primary reasons for the growing popularity of these designs. Recent data collection shows that not only are front access batteries safer, they also provide a longer service life. Field data will be presented from a sample size of over 100,000 12V batteries in UPS applications showing a clear difference in the longevity of front access batteries vs. their traditional top terminal counterparts. Arguments will be made, supported by lab data and flow simulation modeling, detailing why front access batteries are showing longer life, including geometry, internal design, and on-site conditions.

An Introduction to the Nickel-Zinc Battery Chemistry

Nickel-zinc is one of the oldest new battery technologies available today. The first patents issued around the chemistry date to the turn of the 20th century. Patents submitted by de Michalowski, Junger and Edison were all issued in the 1899 to 1901 timeframe. Further development has proceeded in several countries, and by many researchers and manufacturers. There are currently several manufacturers working with nickel-zinc batteries in different areas, and utilizing variations of the basic chemistry. Desirable because of the excellent high rate discharge capability, the chemistry was plagued by the inability for the available technology of the time to control the growth of zinc dendrites in the cells, which lead to internal shorting of the cells. Thanks to the advancement of cell design, new manufacturing technologies, and new battery component materials, nickel-zinc has now become a commercially viable battery chemistry. This paper will address nickel-zinc batteries from three perspectives: 1) An introduction to the chemistry and construction of nickel-zinc batteries; 2) Third party test data; 3) Current nickel-zinc battery uses and applications.

The Pros and Cons of Using Standby Batteries for Grid Services

The growing deployment of lithium-ion (Li-ion) batteries in data centers is prompting discussion on the potential use of those batteries to provide some level of grid services, such as regulation or primary frequency response. Indeed, in the energy storage world it has long been the aim to address multiple applications to create stacked financial benefits, so it seems logical to consider using these batteries for grid services while maintaining an energy reserve for standby operation. The cycling capability of most Li-ion batteries certainly can support this type of use, but is it a good idea? This paper provides information on the operation of Li-ion energy storage systems in regulation and frequency-response applications, and how these services can be adapted for data-center batteries. The dynamics of markets for these services are also discussed. It will be seen that this combination of applications, while technically feasible, is not without complications.

VRLA Batteries Compared to LTO Batteries in UPS Applications

Uninterruptible Power Supplies (UPS) have evolved over the years to become increasingly more efficient in terms of their energy usage and space usage, but batteries, essential components of this back-up power system, have not been updated with the latest technology for several decades. This paper aims to highlight the differences in performance of valve-regulated lead acid (VRLA) and lithium titanate (LTO) batteries with respect to their discharging rate, cycle and shelf life, safety, specific energy, and costs by building a total cost of ownership (TCO) model in an UPS application with the goal of demystifying the battery selection process so that customers can make informed choices.

Thermal Runaway Prevention, Detection, and Recovery – VLA or VRLA Cells

This paper is being written specifically for those individuals that perform the actual hands-on maintenance on their battery systems. Since you are the first line of defense against Thermal Runaway and unexpected battery failures, you need to understand more about your batteries than anyone else in your company. Why? Because you are ones that are taking the actual measurements, and observing what is occurring with that battery at that date and time. By your understanding what is normal and what is not for that particular battery, you can alert your upper management to an issue in progress that needs to be addressed to protect your revenue producing equipment, the site, and even the personnel. If someone higher up the food chain decides to ignore your report, or to not take corrective action, for whatever reason, you will have at least documented your findings, and done your job. The pictures are from multiple sites and multiple manufacturers.

Temperature Impacts on Ohmic Value in the Real World

For most manufacturers Lead Acid batteries perform optimally at or around 77-degree Fahrenheit. Therefore, many applications operate the battery at that temperature. What about the applications where it isn’t cost-effective to control the temperature? We all know the battery will not perform as well and will have a shorter operating life but how do we monitor and manage those batteries? Ideally, we’d like to keep the batteries which are treated poorly close to ensure we could measure them frequently and correct any issues promptly. But unfortunately, many of the batteries exposed to the most severe operating conditions are those located in remote sites where access is extremely limited. This paper will characterize users and cases where batteries are operated in an extreme temperature environment. Many utilities have small switch stations with no environmentally controlled station house. They are often deployed in a metal box exposed to the environment amplifying the extremes of the environment and sometimes temperatures reach well above the highest ambient air temperature measured outside the enclosure. Here the batteries are operating at temperatures from below 0 to greater than 120 degrees Fahrenheit. With the proliferation of NERC maintenance regulations, the health of batteries is aggrandized.

Standardizing Alternative Battery Technologies for Utility Applications

Manitoba Hydro is typical among electric utilities in relying primarily upon traditional Vented Lead-Acid (VLA) batteries for station standby applications and for expecting them to remain operational for approximately twenty years. Manitoba Hydro has worked with the University of Manitoba over the last three years to evaluate the performance of Lithium-Ion and Sodium-Nickel batteries and their applicability to electrical substation use. Some of the initial study results enabled Manitoba Hydro to determine these batteries' aging characteristics, outline suggested maintenance practices, and provide an initial health index scoring system for electrical utilities' reference. These conclusions were provided at Battcon 2018 and at the CIGRE Canada 2018 electric utility industry conference in order to both encourage industry discussion and to receive professional critique from the relevant subject matter experts. This paper builds upon Manitoba Hydro's previous work by proposing a methodology for standardizing Sodium-Nickel and Lithium-Ion battery sizes and voltages for station standby applications. This proposed methodology will be experimentally verified by using actual utility-grade discharge profiles for both transmission and distribution substations. This paper will hopefully address utility concerns involving these new technologies and facilitate the eventual transition to such technologies as they become increasingly cost-effective. It is also intended to provide both manufacturers and utilities an independent experimental and theoretical reference point when designing or explaining such product performance.

New Developments in Safety Compliance for Battery Energy Storage Systems

Battery powered stationary energy storage systems (BESS) are rapidly being deployed across the world, and the codes, standards, and regulations that manufacturers and installers are required to meet are rapidly evolving. Many companies do not have extensive experience in navigating the maze of codes, standards, and regulations (CSR) required for these systems, especially in the current climate where the CSR landscape is still under development. This paper will provide an overview of the primary codes and standards related to the manufacture and installation of BESS, along with an explanation of some of the latest developments in the codes and standards landscape for BESS. This will include standards such as UL 1973 and UL 9540, as well as the new fire test procedure UL 9540A and the latest code development, NFPA 855. An explanation of how the standards are implemented across different technologies such as lithium-ion, lead acid, and flow batteries will be discussed. Other currently evolving topics will be presented such as cyber security and functional safety (term for evaluation of the software and electronic controls used for primary safety in the system). Methods for gaining system compliance will be presented, including model certification and field evaluation.

Understanding UL Safety Standards as Applied to Battery Systems

Numerous existing and emerging fire codes which address battery energy storage systems reference UL standards as an essential element of installation safety. The most commonly referenced UL standards need to be correctly understood and applied to ensure cost effective compliance. For instance, UL9540, Standard for Energy Storage Systems and Equipment, applies at the system level to a broad class of energy storage systems. For energy storage systems that utilize batteries, UL9540 requires compliance to UL 1973, Standard for Batteries for Use in Stationary, Vehicle Auxiliary Power and Light Electric Rail (LER) Applications. But UL 1973 is not applicable to lead acid batteries. Lead acid batteries are addressed in UL standard 1989, Standard for Standby Batteries, which is not cross referenced by UL 9540. In addition, for a UPS system, the applicable UL standard is UL 1778, Uninterruptible Power Systems. UL 1778 is also not referenced by UL 9540 nor vice-versa. UL 1778 does reference UL 1989, but not UL 1973. This paper provides an overview of the complex web of UL safety standards as applied to batteries and provides a useful flow chart that can be used to determine which standards should be applied based on battery chemistry and installation application.

DC Plant Modification Mishaps (and how to avoid them)

During last summer's IEEE Energy Storage and Stationery Battery Committee meeting, there was considerable interest in a presentation by Telcordia's Service Line Director, Richard Kluge. A large part of his discussion centered around several major incidents in the telecommunications industry. Due to time constraints, Mr. Kluge covered only high-level details about any of the events. The lessons to be learned from those and similar incidents bear sharing because many older plants are still in service. The purpose of this paper is to cover several such incidents in greater technical detail and show 'take-away' learning concepts to prevent such failures going forward. Incidents covered include: a large battery fire, vibrating bus bars in a dc plant, countercell modification error, and EPO error.

Solutions for High Temperature Lead Acid Batteries

The impact of impurities in the raw materials of industrial lead acid batteries is widely known. In particular, Fe and Bi are two elements that are known to negatively impact battery life. A third specific impurity has been discovered, that even in miniscule amounts, affects life performance of lead acid batteries. We have identified this impurity using specialized analytical methodologies and measurement technologies and named it “Element-X.” The 99.99% requirement for purity of electrolytic lead still allows ppm level impurities. However, when the amount of Element-X in electrolytic lead is controlled to the ppb level, float life is greatly improved. Element-X promotes the following degradation in battery cell performance. In summary, Element-X accelerates anode and cathode deterioration and shorter float life. Accelerated life test data is also benchmarked as a proof point of the impact of Element X reduction.

Functional Safety and Li-ion Batteries

A number of industry standards have been developed to address functional safety for a variety of applications. As an example, IEC 61508 is a general functional safety standard that addresses the lifecycle of electrical systems. This standard defines functional safety as the detection of a potentially dangerous condition resulting in the activation of a protective or corrective device or mechanism to prevent hazardous events from arising or providing mitigation to reduce the consequences of the hazardous event. The concept of functional safety is gaining importance in a variety of industries due to the increasingly sophisticated system architectures and controls. Functional safety can also play an important role in the context of larger Li-ion battery systems. As the use of Li-ion cells in large-scale energy storage applications expands, the need to use functional safety concepts when developing these battery systems becomes greater. This paper will provide an overview of functional safety as addressed in some of the industry standards, and, through an example, demonstrate how the concepts can be used when developing a Li-ion battery system for a large-scale energy storage application. A similar approach can be adopted while developing battery systems involving other chemistries.

A Methodology for Evaluating the Root Cause of a Li-ion Battery's Failure

Lithium-ion (Li-ion) batteries are present everywhere from mobile phones to electric vehicles. In some instances, a Li-ion cell may experience an energetic failure where the cell fails exothermically — referred to as the cell going into “thermal runaway.” Although infrequent, failures such as this can be destructive and pose a fire hazard. With an increasing penetration of these batteries in a variety of industries, the need for a better understanding of the causes of battery failure and failure mechanisms has also increased. A Li-ion battery failure can be due to a number of different conditions such as overcharging, overheating, mechanical abuse to the battery or a cell manufacturing defect. Factors such as the electrical and mechanical design of the battery, the overall construction quality of the cells, unforeseen external conditions etc. can all lead to a battery failure in the field. For this reason, when analyzing battery failures, a defined and systematic approach must be used to evaluate all potential causes of failure. This paper presents a failure analysis approach that can be used when determining the root cause of a battery’s failure. The steps that can be used to reach a root cause of failure will be demonstrated through a case study.

Taking Advantage of Long Life Alloys

Following up last year's paper "Impact of Alloy and Geometry on VLA Positive Grid Designs," this paper will look at how higher specific gravities will react in modern VLA cells. Historically a 1.215 specific gravity was required to achieve 20 years of life. Raising your specific gravity to increase energy density or freezing point would result in a reduction in anticipated battery life. This holds true, but the question is, with modern VLA batteries no longer failing due to grid corrosion, can you achieve 20 years of life at 1.250 specific gravity? How about 1.300? This paper will explore the impact of higher specific gravities on longevity and how they can be used to save footprint and string count without sacrificing longevity.

What is a Pure Lead Battery and Why Do I Need One?

Batteries marketed as Pure Lead are gaining popularity in the datacenter, telecom and utility segments. Pure Lead batteries come in different forms and different designs, but there is no standard to meet in order to call a battery "Pure Lead." This paper will answer the question "What is a Pure Lead Battery?" and explore the potential benefits to the end user while educating them on what questions to ask to ensure their battery has the features needed to support their application.

Can a Legacy Lead-Acid Battery Actually Be Considered an "Advanced" Lead-Acid Battery, and Can it Play an Effective Role in Energy Storage?

Most RFP's for energy storage rule out lead-acid batteries as a consideration. The emphasis with pilots and grants to date have centered on several technologies to the exclusion of lead-acid. This begs the question, is the lead-acid battery in danger of becoming obsolete relic in the not too distant future? Further, are there distinctions between legacy lead-acid batteries and "advanced" lead-acid batteries, and if so, what are they? Finally, can a traditional standby lead-acid battery provide a reliable and effective solution for certain energy storage applications, especially with renewables like solar + storage? This paper will answer these questions and make the case that certain lead-acid batteries should not be negatively ruled out-of-hand. There are several learning objectives for this paper. Comparing the difference in "legacy" vs. "advanced" lead-acid battery characteristics and performance expectations as well as understanding when overlap situations exist. Understanding the requirements for a renewables (solar) plus storage application, including existing standards (best practices) that address these requirements. Examining the IEC testing results that support both traditional standby performance and "advanced" lead-acid battery requirements. Confirming that certain advanced lead-acid batteries deserve to be included as an acceptable, alternative solution for these application areas.

Cell Simulation Hardware for Safe and Efficient BMS Testing

Many battery and energy storage system manufacturers and users utilize live cells for testing the electronic subsystems, including the battery management system (BMS), cell monitors, safety interlocks, charging systems and master controller. There are problems with this approach in the various stages of battery system design, development and production. First and foremost is safety. Li-Ion cells, in particular, are hazardous and may be subject to thermal runaway. Second is repeatability. The characteristics of cells change with every charge and discharge cycle. The third is efficiency. It is time consuming to charge and discharge cells in order to test the electronics at various states of charge. This makes many test procedures unnecessarily lengthy. Finally, use of real cells limits test coverage of the associated electronic subsystems to the to the SOC capabilities of the specific cells that are used. This prevents the test equipment from physically testing any and all scenarios that cannot be safely exercised with live cells. In this presentation, the paper will discuss BMS and battery electronic test techniques using commercially available cell simulators and fault insertion units.

A Real World Result From Machine Learning

Many examples of theoretical machine learning systems have been presented in the literature and at previous Battcon conferences. This paper is the story of the real-world outcome and lived experiences of a deep analysis of a large portfolio of Uninterruptable Power Supply (UPS) batteries across the US. The project resulted in identification of battery strings and units determined to be at risk, but otherwise not in alarm state within the dimensions of age, voltage, temperature and ohmic readings. Within this broad portfolio, the team identified two battery strings consisting of 40 units that were the highest risk in the customers portfolio. The team then deployed a skilled, trained and equipped field engineering group to remove the battery strings from service and perform a discharge test to compare and validate the machine learning predictions against outcomes. This paper presents the methodology utilized, the decision process to create health and risk scoring, then the detailed results of discharge tests at two sites.

Finding That Elusive Ground Fault

In PRC-005 the three parameters of a DC system that are required to be checked and verified most frequently are the system voltage, electrolyte level (for VLA and NiCad) and for unintentional grounds. Checking for that ground fault is relatively simple and many battery chargers incorporate a ground fault detection system which will generate an alarm if a ground fault is detected. The problems start when you try to find where the ground fault exists within the DC power system. This paper will provide a quick overview of the most typical methods by which ground faults are identified and the potential impact that the methodology used has on finding the actual location of the fault. This will be followed by a review of the most often suggested methods by which the location of the fault can be identified, and an explanation as to the potential risks associated with many of these methods. An explanation of how a low frequency AC signal can be used to locate the ground fault and the limitation that might have with the use of microprocessor-based controls rather than relays. Case studies will be used to demonstrate the challenges that occur in trying to find that elusive fault.

Battery Sizing – Moving It Forward

Battery capacity determination has always been a source of fascination for scientists and engineers dating back to origins of the technology. The first sizing standard for lead acid batteries was published by IEEE in 1978. While sizing for NiCad battery was established using a similar technique shortly after, there has been limited advancement in these methods. The battery industry has yet to come to a consensus on a standard method of sizing for other technologies based on lithium, nickel, zinc, vanadium, and others. In order to create a more comprehensive and industry-wide approach to battery sizing, this paper dives deeper into existing standards by identifying gaps and limitations. Practical limitations are tested using a hardware setup dedicated to sizing, and incrementally adding load steps. A second test is presented by using a sample 24 hours time series load profile and simplifying it by reducing the number of steps that best describe it. The accuracy of simplification vs. time saving for calculations is evaluated. Missing sizing parameters explored include, incorporation of state of charge, cycling as a function of depth of discharge, and consideration for multiple random loads with various time periods.