HOW THE CURRENT DRAFT STANDARD OF NERC PRC-005-2 MAINTENANCE REQUIREMENTS WILL REDUCE BATTERY SYSTEM RELIABILITY

Peter J. DeMar
Founder
Battery Research and Testing, Inc.
Oswego, NY 13126

ABSTRACT

The very first sentence of the opening page of the NERC website states that the NERC mission is to ensure the reliability of the North American bulk power system (BES). However when you read the requirements of PRC-005-02-Protection System Maintenance Tables 1.4 (a), (b), & (f) for stationary battery systems, it is observed that it allows the user to utilize internal ohmic measurements in place of load tests to determine the that the battery will perform as designed. Instead of ensuring the reliability of the battery systems, the real end result for anyone that follows that option is going to end up with decreased reliability. This paper will document how the reliability will be degraded if Tables 1.4(a), (b), & (f) remain as proposed, and will question why PRC-005-02 repeatedly mentions the IEEE 450, 1188, & 1106 documents but ignores the expert advice and proven reliability that comes from following those documents. There has never been a failure of any battery that supported any BES equipment that was being maintained following the applicable above listed IEEE document that this author knows of.

INTRODUCTION

From reading the history of NERC from the Company Overview from the NERC web site it is easy to see that since the beginning in 1962-1963 when "The electricity industry created an informal, voluntary organization of operating personnel to facilitate coordination of the bulk power system in the United States and Canada. Four interconnected transmission systems were connected to three more systems, forming the largest electricity grid in the world." Through the varying regional black-outs and name and responsibility changes, to the present NERC, the goal has pretty much remained the same. That is to improve and assure the reliability and operability of the BES (Bulk Electric System).(1)

The list of participants and organizations that were and are a part of NERC is a complete assembly of every interested party imaginable. Some of the various blackouts are as follows: November 9, 1965 affected 30 million people in the northeastern US and southeastern Ontario Canada, July 13-14 1997 in New York City, two in the western US in 1996, and then the biggest one in North American history that affected over 50 million people on August 14 2003 (Figure 1). Just so that we do not think that these were all from many years ago just last year on September 8, 2011 there was one that affected parts of AZ and southern CA (Figure 2). With all of these events occurring, it is easy to see why there is a need for a central controlling organization that has the responsibility and authority to enforce proper actions to ensure the reliability of the BES in North America. It is important to remember that the BES purpose is to transfer bulk power (2) and these incidents were a failure to be able to do that.

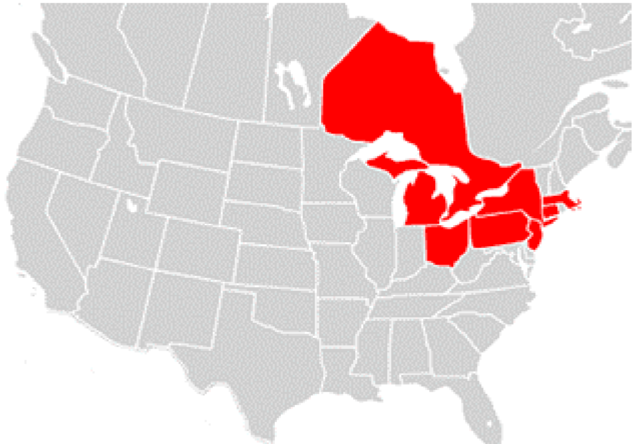

Figure 1. August 14, 2003 50,000,000 effected

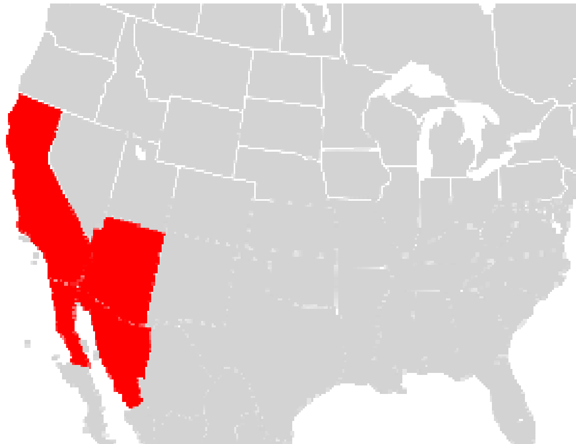

Figure 2. September 8, 2011 5-7,000,000 effected

As everyone in this room, or anyone that reads this paper knows very well, there are many times in life when you realize that something is in need of repair, but it has not completely failed (as far as we know at that moment in time) and it gets reported, but money or resources are tight and we are informed that it will have to wait, or that we will have to risk it. Most everyone has been put in that situation, or knows of someone that has. Usually there is no need for the device to be called upon but when there is and the device fails to work when needed there is a catastrophe. One only has to look back as far as January 26, 2011 and the Kensington substation fire in Kensington MD to see a good example of battery issues that had been observed by those responsible for maintaining the batteries, and reported on during each of the previous semi-annual inspections(4). No action was taken to correct the situation and eventually in a storm the battery eventually failed with the result of a huge fire at the substation, much equipment damage, and a loss of power to a number of residents. No this was not a BES covered substation. This information is provided to emphasize that there has been, and is a very real need for NERC, to assure that things that need to be done to assure the BES reliability are actually performed, documented and reported.

It is hard to believe that it has been 50 years since the group that is now NERC was created, and how many hundreds of thousands of man-hours must have gone into this. Though NERC is a corporation with paid personnel, there are still thousands of people from various interested parties that devote part of their time into the betterment of the effort to improve the BES. All of us that benefit from their efforts need to appreciate what they are doing and thank them for their efforts. However with that being said, the part of the proposed PRC-005-2 that covers maintenance and testing of the battery systems appears to be built on desires instead of proven methodologies.

RELIABLE AND PROVEN PROCEDURES THAT HAVE STOOD THE TEST OF TIME

Since the battery systems of the BES normally are either Lead-Acid or Nickel-Cadmium, and either Vented or Valve Regulated, there are and have been for many years, documents and standards that instruct users in how to maintain and test the respective battery technology to assure reliability and capability. These standards are the IEEE 450 for VLA batteries, IEEE 1188 for VRLA batteries, and IEEE 1106 for NiCad batteries.

As most people in this industry understand, the original IEEE 450 standard was originally created in response to a need for a way to verify that station batteries that were installed in a Nuclear Plant that were safety related would function as required when needed. In other words a battery or batteries could provide the power to safely shut down the reactor in an emergency when a loss of AC power occurred. There is no more important function than this for any battery that you or I are ever going to be involved with. This standard through the years has undergone changes and improvements and applies to all VLA batteries. It does not matter if this is as critical as a safety related nuclear application, or if it be a small distribution substation battery, this document has stood the test of time in being the only sure way of assuring reliability and predictability with this type battery. One only has to look at the recent events in Fukushima Japan to get a feel for what can go wrong when a safe shutdown cannot be accomplished at a nuclear plant. I am not saying here that the batteries had anything to do with the failure, just stating what some of the consequences can be when the reactors cannot be shut down safely.

While IEEE 1106 for maintenance and testing of Nickel Cadmium batteries and IEEE 1188 for maintenance and testing of VRLA batteries are newer documents than the original IEEE 450, they also are the best available procedures for providing maintenance and testing practices to assure reliability and predictability.

As far as this author knows there has never been a documented failure of any of these three type batteries when they have been maintained and tested following the applicable document. Yes there have been unexpected failures with batteries of each of these types in all types of applications, but not when these IEEE documents were being followed as written. When the maintenance and testing is performed as listed in these documents there always is advanced warning provided of issues that will affect the operability or capability of the battery. I challenge anyone to show us the documentation that demonstrates that there has been. Yes many users have given lip service to their following this or that document when in reality they have performed none of the load testing and only partial implementation of the recommended maintenance checks.

However as we all know when a failure occurs it is all too often common practice to cover up the fact that these IEEE practices which were developed to assure those that followed them that their batteries would perform as needed when called upon, were not being followed, and instead there had been more concern about cutting the maintenance budget than being sure that the battery would work when needed.

NERC REQUIREMENTS FOR BATTERY CHECKS

The applicable NERC document that covers the requirements for stationary battery maintenance/testing is the proposed Standard PRC-005-2 – Protection system Maintenance and Tables 1-4(a) – (f) covers the requirements for Protection System Station dc supply using either VLA (1-4(a)), VRLA (1-4(b)), or Ni-Cad (1-4(c)) batteries as well as those Using Non Battery Based Energy Storage (1-4)(d), and a section titled Exclusions for Protection Systems Station dc supply Monitoring Devices and Systems (1-4(f)).

The following chart shows the minimum maintenance actions presently proposed and allowable, and the intervals when the Protection System Station dc Supply is using a VLA, VRLA, or NiCad battery. I have not included in this chart Table 1-4(d) as it is for Non Battery Based Energy Storage system. Nor did I include 1-4(e) requirements as they are for non BES Interrupting Devices. I did include Table 1-4(f) which allows exclusions to the time intervals for a human to even enter the battery room if a monitor is connected and continually monitoring and alarming the listed functions.

Table 1. Maintenance intervals allowed between someone actually going into the battery or charger room.

Time interval	VLA Table 1-4(a)	VRLA Table 1-4(b)	NiCad Table 1-4(c)	Table 1-4(f) monitored
4 calendar months	Verify; Station DC supply voltage Inspect; Electrolyte levels For unintentional grounds	Verify: Station DC supply voltage Inspect: For unintentional grounds	Verify: Station DC supply voltage Inspect: Electrolyte levels For unintentional grounds	No periodic maintenance specified
6 Calendar Months		Measure all battery cell/unit internal ohmic values		No periodic maintenance specified
18 Calendar Months	Verify: Float voltage of battery charger Battery continuity Terminal and cell to cell connection resistances, Inspect: All cells visually OR measure ohmic values of all cells where the cells are not visible Physically inspect racks	Verify: Float voltage of battery charger Battery continuity Terminal and cell to cell connection resistances, And physically inspect rack	Verify: Float voltage of battery charger Battery continuity Terminal and cell to cell connection resistances Inspect: all cells visually physically inspect racks	No periodic maintenance specified
6 Calendar Months OR 3 Calendar Years		Verify battery can perform as designed by evaluating measured cell/unit internal ohmic values Or Verify battery can perform by running a load test every 3 years		No periodic maintenance specified
18 Calendar Months OR 6 Calendar Years	Verify battery can perform as designed by evaluating ohmic values every 18 months Or Verify battery can perform by running a load test every 6 years			No periodic maintenance specified
6 Calendar Years			Verify battery can perform as designed by running a load test	No periodic maintenance specified

These NERC requirements are the minimum required, and the maximum time interval between performing these actions. Users can and should follow a more stringent maintenance and testing regime than what is listed in those tables if they want to ensure reliability of their battery systems.

What is wrong with these requirements?

- There are no requirements for measuring individual cell voltages.
- There are no requirements for measuring float currents which is the preferred method for determining state of charge with Lead Calcium VLA, and VRLA, and NiCad batteries, as well as it is a very early indicator of other internal issues with VRLA batteries.
- There are no requirements for measuring ambient temperature, or cell or electrolyte temperatures. As has been well understood for a number of years a wide temperature differential between the cells and the ambient is an alert that a problem is occurring inside of the battery, particularly with VRLA cells.
- They incorrectly assume that ohmic values can be used in place of load testing.

In the Supplementary-Reference-and-FAQ-redline-2011815.pdf DRAFT 1 July 29,2011. In Section 8.1.2 Additional Notes for Tables 1-1 through 1-5 paragraph 4(5) refers to IEEE 450, 1188, and 1106 and states that these are appropriate procedures, but it then ends with the following sentence. However, the methods prescribed in these IEEE recommendations cannot be specifically required because they do not apply to all battery applications. I have to question just what other battery applications that the document is referring to, since the three tables 1-4(a), 1-4(b), and 1-4(c) are for VLA, VRLA, and NiCad batteries, and it is my understanding that within the BES system that these three types of batteries must be at least 99% of the population. The only reason that I do not say 100% is that there may be other battery chemistries installed out there, but I do not know what they are, as I only find those three listed in the NERC tables.

What would make the authors of the PRC-005-2 think that ohmic values equate to capacity?

In section 15.4.1 Frequently Asked questions: in the above listed document, on page 76 it states "For lead acid batteries the ability to perform as designed can be determined in more than one manner." This is just not true, as only a discharge test of some kind can determine the ability of the battery to perform as designed. There is no other way! Yes there are other checks that can be made to determine if there is degradation of some kind occurring that can have varying impacts on the ability of the battery to properly perform its required functions, but none of them alone can determine that ability. Of course an open cell can tell you that the battery will not perform, but a poor ohmic value only tells you that the cell (or cells) has some sort of an issue that is impacting that ohmic measurement.

This same section goes on to state that "The two acceptable methods for proving that a station battery can perform as designed are based upon two different philosophies." The first being that you can use ohmic values to determine if each cell can perform as designed and therefore the entire battery can be verified to perform as designed. This is absolutely incorrect. The second method is to run a load test. This is the only proven way to determine if the battery will perform as designed.

Also in this section is the following statement: The first maintenance activity listed in Table 1-4 for verifying that a station battery can perform as designed uses maximum maintenance intervals for evaluating internal ohmic measurements in relation to their baseline measurements that are based on industry experience, EPRI technical reports and application guides, and the IEEE battery standards.

I do not have access to EPRI reports and I cannot find the exact document that NERC is quoting from. However I do have the BATTCON 2002 paper titled "Internal ohmic measurements and their relationship to battery capacity – EPRI's ongoing technology evaluation" (6). When I read this paper I come up with the conclusion based upon the data in the paper and the concluding remarks, that ohmic evaluation cannot predict battery capacity or capability. In fact in the concluding remarks it clearly states that the technology will likely be limited to identifying good or bad cells rather than making claims that a certain internal resistance indicates a particular cell capacity. It further states that ohmic measurements can identify low capacity cells however the technology does not precisely predict overall battery capacity. If you need an accurate measure of the overall battery capacity, perform a battery capacity test. If those responsible for NERC making the statement that ohmic value is a valid substitute for actual discharge testing have data that is not that EPRI report (as that report certainly does not suggest or condone substituting ohmic measurements for capacity testing), I would be very interested in seeing that data. It would be an easy bet that others involved in the IEEE Stationary Battery Committee would also like to see that supporting data. As Dr. Feder who, for the past forty years has been one of the leading experts in the stationary battery field would say "show me the data".

Zbig Noworolski of Polytronics Engineering and Infobatt presented a paper at Intelec 2002 titled "Can a Battery Ohmic Tester Distinguish a Good Cell From the Pool of Better Ones?"(7). In this paper credit is given to using ohmic values as a diagnostic tool but it specifically does not recommend this as a replacement for a capacity test as there is not a correlation between ohmic measurements and capacity that can be relied upon. It is stated that above 60% of capacity the relationship of ohmic measurements to capacity is questionable and above 80% of capacity it is practically nonexistent.

At Battcon 2006 there were two papers presented that reported on the respective battery manufacturers' positions on using ohmic measurements to determine capacity. The first was by John P. Gagge of Enersys and was titled "Ohmic Readings: A Battery Manufacturer's Perspective" His paper was a report on the results of over two years of work with two different manufacturers of test equipment. It concluded with "At this time, ohmic measurements have not proven to be a fully reliable substitute for capacity testing and should not be used to predict absolute capacity values." (8)

The second paper presented was by Robert Malley and Allan Williamson of C&D Technologies and it was titled "Relation of Conductance to Capacity Over the Life of Large Format VRLA Products" (9). They stated "There were wide variations in the relationship between capacity and conductance between the different brands. The behavior ranged from a roughly linear response, to no change in conductance with wide changes in capacity, to wide changes in conductance with small changes in capacity. The correlation between capacity and conductance within brand types was poor enough to place significant doubt on the practice of replacing capacity testing with conductance testing. The data simply do not show the R2 values of 90 or 95% required to make economic decisions using regression data." They go on to say that they do not intend to infer that there is not value in using ohmic values for monitoring VRLA products as they can be used both in the lab and in the field. However they do end the paper with "these readings should not be used alone as an absolute judge of product performance".

The authors of all four of these papers give credit to using ohmic measurements to find issues, and state that it is a valuable tool, however they all also unanimously rule out using ohmic measurements to determine capacity or capability.

Everyone should understand that internal ohmic measurements were developed to help determine when there was some sort of an issue occurring inside of a VRLA cell that had not yet decayed to the point that it impacted the cell voltage. It was created as a means to accomplish what the human eye could observe in most vented cells. That is the internal conditions. It has become much more than that and is a critical part of any maintenance program, especially for VRLA cells. However it never has and does not now prove capacity or capability. As everyone understands the amount of ohmic degradation has differing impacts on the ability of the battery to perform. An ohmic degradation that has a minor impact on a lightly loaded battery such as a Telecom one could be a substantial impact on one that is heavily loaded, such as the inrush of lube oil pumps and turning gears at a power plant.

It is easy to understand why management of the sites that will fall under these rules would prefer to use ohmic values in place of load testing as it requires less manpower and expenses. However I do not believe that the intent of NERC is to allow reduced reliability just because the proper maintenance actions are more costly than actions which will not assure the maximum reliability of the system.

Conclusion

In this author's opinion NERC has introduced a procedure into their requirements for battery maintenance that will reduce the reliability of the BES instead of assuring its reliability, and should correct this error before someone adopts using internal ohmic measurements in place of load testing, and a BES impacting failure occurs. It appears that the attempt to include ohmic measurements as a substitute for load testing was written with "cost saving" intentions trumping "reliability based" ones.

Surely Battcon, Intelec, or any other industry related conference would welcome papers that demonstrate that there is a good correlation between internal ohmic measurements and capacity or capability. However until such time that this occurs, it is a bad idea as there is not sufficient data to provide evidence that ohmic testing is a substitute for load testing.

Yes ohmic testing is less expensive and is a valuable maintenance tool, but it does not prove capacity or capability. However is the goal of NERC to reduce the cost of assuring reliable systems or is it to assure the reliability of the BES? Of course it is the latter, but allowing ohmic measurements to be a replacement for load testing is a step in the opposite direction.

One would also wonder if any of the entities that provide insurance for these users whose systems are categorized as part of BES would provide coverage with just the proposed NERC requirements allowing ohmic testing in place of capacity testing as the deciding factor if a battery is capable of supporting the equipment loads or not. It would make sense for an underwriter at a carrier to include some sort of wording that that clearly stated that if the user elected to utilize ohmic measurements over load testing that any coverage related to a failure would be severely impacted.

REFERENCES

1. www.nerc.com Home Page first paragraph
2. PRC-005-2 Draft July 29, 2011 Supplementary_Reference_and_FAQ_redline_20110815.pdf Page 6 Section 2.3 first sentence
3. Wikipedia maps of blackouts in North America
4. http:// kensington.patch.com/articles/kensington-substation-fire-caused-by-battery-system-failure
5. PRC-005-2 Draft July 29, 2011 Supplementary_Reference_and_FAQ_redline_20110815.pdf Section 2.3 first sentence
6. Battcon 2002 “Internal ohmic measurements and their relationship to battery capacity – EPRI’s ongoing technology evaluation”
7. Intelec 2002 “Can a Battey Ohmic Tester Distinguish a Good Cell From the Pool of Better Ones?”
8. Battcon 2006 “Ohmic Readings: A Battery Manufacturer’s Perspective
9. Battcon 2006 Relation of Conductance to Capacity Over the Life of Large Format VRLA Products