NERC PRC-005-2: A Mandate for Battery Maintenance and Its Implications for Battery Maintenance Personnel

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Abstract

After the catastrophic blackout of August 14, 2003, increasing sensitivity to the interconnectivity and reliability of the Bulk Electric System (BES) has become a major focus of the Federal Electric Reliability Commission (FERC). As a result, FERC established the Electric Reliability Organization (ERO) of which NERC (National Electric Reliability Corporation) was given responsibility to generate standards that would ensure complete reliability of the BES.

One of those standards, PRC-005-2[1] now requires utilities to mandate certain minimum maintenance requirements for batteries that interface with equipment connected to the BES within a prescribed maximum time interval.

This paper provides a brief history while examining the requirements laid out in the new NERC-PRC-005-2 standard. NERC PRC-005-2 was adopted by the NERC Board of Trustees on November 7, 2012, and submitted to FERC for final regulatory approval on February 26, 2013.

Since this standard encompasses all electric utility functional entities, including substations and power generating plants, the paper will examine the NERC definition of "reliability" as contrasted with that of the IEEE Stationary Battery Committee's definition of "reliability" as it relates to batteries. The paper will also provide a practical guide on how battery maintenance personnel can meet the requirements of PRC-005-2.

To accomplish this, the authors explain the thought process and deliberations behind the final wording concerning the battery maintenance tables in the body of the document. The authors then summarize the lengthy supplemental materials and provide recommended guidance that will allow users to correctly perform battery maintenance while meeting the PRC requirements.

Background

NERC is a nonprofit corporation. Their main mission is to ensure the reliability of the Bulk Power System (BPS) in North America.

FERC is a US government regulatory agency. Among FERC's many responsibilities is the regulation of the interstate transmission of electricity.

On August 14, 2003 at 4:10 pm EDT, 50 million people lost power in the northeastern and midwestern United States as well as Ontario Canada. This was actually the second major blackout in post-war America – the first one occurring on November 9 of 1965. That one took out the whole Northeast as well.

As a result, Congress passed the US Energy Act in 2005, better known as the Electric Modernization Act of 2005. This act authorized FERC to designate an Electric Reliability Organization, or ERO, by which NERC became the franchise owner of its role for the BPS. The ERO designation authorizes NERC to create and enforce standards upon the suppliers to the BPS.

FERC defines that the BES " includes all facilities operated at or above 100 kV and a list of configurations that are deemed to be, regardless of their voltage rating, included as part of or excluded from the BES. Facilities that are deemed to be included in the BES are subject to compliance with NERC Reliability Standards." [2]

On July 19, 2007 FERC issued Order 693 that mandated 83 NERC reliability standards be established and implemented. PRC-005 was one of those 83 standards. At this time, a Glossary of definitions was established that defined reliability as "ensuring that the Bulk Power System is able to meet the electricity needs of all end-user customers, even when unexpected equipment failures reduce the amount of available electricity." [3]

PRC-005 is the standard that is designed to ensure that every functional entity has developed and implements a solid maintenance program that covers all of their Protection Systems. The maintenance of the Protection Systems ensures that the Bulk Electric System (BES) removes the least amount of electrical equipment for electrical faults (permanent or temporary) while still meeting the electricity needs of most end-user customers. PRC-005-002 is the latest update to this standard, although a PRC-005-3 is currently under development to address reclosing relays.

There are five fundamental components that are addressed in PRC-005-2. These make up the protection and control system as defined by the standard, and include [1] protective relays, [2] associated communication systems, [3] voltage current and sensing devices, [4] control circuitry as well as [5] the station dc system. The station battery along with battery chargers make up the major part of the station dc supply.

PRC-005-2 mandates that each functional entity must have an established Protection System Maintenance Program (PSMP), and this PSMP allows for two types of maintenance methods: performance-based, and time-based methodologies.

The performance-based type of maintenance method allows Protection System owners to extend the maintenance interval for a maintenance activity of a certain component by keeping maintenance records of the component and using statistics to extend the maintenance interval for that specific component.

The performance-based type of maintenance method can be used for every protection system component with the exception of the station battery. Station batteries were excluded from any performance-based maintenance program because there are too many variables in the electrochemical process to completely isolate all of the performance-changing criteria necessary for using a performance-based type of maintenance method although a work-around exists to some degree through one of the tables that we will address.

Time-based maintenance is the process in which Protection Systems are maintained or verified according to a defined time schedule and this is the process required for the station battery.

Note: The terms BES (Bulk Electric System) and BPS (Bulk Power System) essentially mean the same thing in context, and are used interchangeably in this paper.

Recent activity of PRC-005-002

At the 2012 Battcon Conference, two papers given by members of the IEEE Stationary Battery Committee registered concern over implications regarding reliability as it pertained to stationary batteries as outlined in NERC PRC-005-2. This followed a meeting of the Stationary Battery Committee (SBC) in January of 2012 where a Task Force was commissioned by the Committee to review the current draft of the PRC-005 standard and make recommendations as to appropriate actions the Battery Committee should take in light of the statements contained in the draft standard as it relates to battery maintenance.

By the time the SBC task force became involved with the standard the NERC team was already in its third draft revision and was preparing to release the final proposed draft standard for ballot among voting members of NERC.

However, the Stationary Battery Committee representatives were permitted to express their concerns and moderate a conciliation to both the Standard and the Supplemental Reference Guide/FAQ. These are now incorporated in the final Revision 4 of the Standard. This revision was adopted by the NERC Board of Trustees on November 7, 2012, and submitted to FERC for regulatory approval on February 26, 2013.

PRC-005-002 Station Battery Maintenance Requirements

PRC-005-002 dictates the minimum maintenance activities and maximum time intervals for battery maintenance. These activities and intervals are provided for vented lead-acid, valve regulated lead-acid and nickel-cadmium batteries. These requirements can be found in PRC-005-002 in Tables 1-4 a, b, and c.[1] as shown below:

Table 1-4(a)
Component Type - Protection System Station dc Supply Using Vented Lead-Acid (VLA) Batteries
Excluding distributed UFLS and distributed UVLS (see Table 3)

Protection System Station dc supply used only for non-BES interrupting devices for SPS, non-distributed UFLS systems, or non-distributed UVLS systems is excluded. (see Table 1-4(e).

Component Attributes	Maximum Maintenance Interval	Maintenance Activities
Protection System Station dc supply using **Vented Lead-Acid (VLA) batteries** not having monitoring attributes of Table 1-4(f)	4 Calendar Months	Verify: • Station dc supply voltage Inspect: • Electrolyte level • For unintentional grounds
	18 Calendar Months	Verify: • Float voltage of the battery charger • Battery continuity • Battery terminal connection resistance • Battery intercell or unit to unit connection resistance Inspect: • Cell condition of all individual battery cells where cells are visible – or measure battery cell/unit internal ohmic values where the cells are not visible • Physical condition of battery rack
	18 Calendar Months or 6 Calendar Years	• Verify that the station battery can perform as manufactured by evaluating cell/unit measurements indicative of battery performance (e.g. internal ohmic values or float current) against the station battery baseline or • Verify that the station battery can perform as manufactured by conducting a performance or modified performance capacity test of the entire battery bank

Table 1-4(b)
Component Type - Protection System Station dc Supply Using Valve-Regulated Lead-Acid (VRLA) Batteries
Excluding distributed UFLS and distributed UVLS (see Table 3)

Protection System Station dc supply used only for non-BES interrupting devices for SPS, non-distributed UFLS systems, or non-distributed UVLS systems is excluded. (see Table 1-4(e).

Component Attributes	Maximum Maintenance Interval	Maintenance Activities
Protection System Station dc supply using **Vented Regulated Lead-Acid (VLA) batteries** not having monitoring attributes of Table 1-4(f)	4 Calendar Months	Verify: • Station dc supply voltage Inspect: • For unintentional grounds
	6 Calendar Months	Inspect: • Condition of all individual units by measuring battery cell/unit internal ohmic values
	18 Calendar Months	Verify: • Float voltage of the battery charger • Battery continuity • Battery terminal connection resistance • Battery intercell or unit to unit connection resistance Inspect: • Physical condition of battery rack
	6 Calendar Months or 3 Calendar Years	• Verify that the station battery can perform as manufactured by evaluating cell/unit measurements indicative of battery performance (e.g. internal ohmic values or float current) against the station battery baseline -or- • Verify that the station battery can perform as manufactured by conducting a performance or modified performance capacity test of the entire battery bank

Table 1-4(c)
Component Type – Protection System Station dc Supply Using Nickel-Cadmium (Ni-Cad) Batteries
Excluding distributed UFLS and distributed UVLS (see Table 3)

Protection System Station dc supply used only for non-BES interrupting devices for SPS, non-distributed UFLS systems, or non-distributed UVLS systems is excluded. (see Table 1-4(e).

Component Attributes	Maximum Maintenance Interval	Maintenance Activities
Protection System Station dc supply using **Vented Lead-Acid (VLA) batteries** not having monitoring attributes of Table 1-4(f)	4 Calendar Months	Verify: • Station dc supply voltage Inspect: • Electrolyte level • For unintentional grounds
	18 Calendar Months	Verify: • Float voltage of the battery charger • Battery continuity • Battery terminal connection resistance • Battery intercell or unit to unit connection resistance Inspect: • Cell condition of all individual battery cells • Physical condition of battery rack
	6 Calendar Years	• Verify that the station battery can perform as manufactured by conducting a performance or modified performance capacity test of the entire battery bank

Table 1-4(f) (Exclusions if using Station dc Supply Monitoring Devices and Systems) follows the concept of performance or condition-based maintenance. This table states that if the owner can monitor with properly verified alarming, no periodic manual maintenance is specified, and therefore by assumption, required. Keep in mind that monitoring of one function does not relieve the functional entity from the requirements of the other functions in the table. In addition, the owner has the responsibility to analyze the readings that are monitored to determine whether corrective action is needed. It should also be noted that although the standard allows continuous monitoring in lieu of visual inspections, visual inspection of condition of the battery is a very important activity in battery maintenance for VLA, VRLA and Ni-Cad batteries. Totally eliminating the visual inspection is not wise.

All functional entities that fall under the facilities requirements of PRC-005- 2 will be required to adopt a Protection System Maintenance Program or PSMP if they don’t already have one. The standard enforces a minimum maintenance requirement with a maximum time interval. Audits are a part of the process; therefore documentation of all completed exercises is required, and fines can and most likely will be assessed for non-compliance.

There is a Supplemental Guide and Frequently Asked Questions (FAQ) document that accompanies the Standard. While this document is not considered an official part of the standard, it does provide interpretation and guidance to the user.

PRC-005-002 Interpretation

While there are many parts of PRC-005-002 and various requirements for the station batteries, the most controversial, and most misinterpreted requirement is the one that gives the user an option to take ohmic readings in lieu of battery capacity tests (for VLA and VRLA cells).

The fact is that PRC-005-002 allows the user to utilize any measureable parameter in lieu of performance tests so as long as the user can demonstrate that the selected parameter is able to determine that the battery will perform as manufactured. The words “perform as manufactured” were chosen carefully. The ultimate measure of a reliable dc system is one that will provide the adequate energy when needed. This requires a knowledge of the minimum energy profile needed by the protection system. In most cases, battery technicians charged with maintaining the equipment would not be aware of the design requirements of the battery. However, the battery technicians can easily determine the battery specifications (as manufactured) and therefore could determine if the battery can meet these specifications. It is assumed that if the battery did perform as manufactured, the battery would be able to meet the minimum energy profile.

The requirement to verify that the station battery can perform as manufactured does not specify the parameter to be used. In theory, any cell/unit measurement can be used as long as the user can provide evidence that the measurement can, with reasonable reliability, determine when the cell/unit/battery will not be able to perform as manufactured.

For most substation users, the measurement of choice will be ohmic readings. However, the use of ohmic readings to determine if a battery can perform as manufactured is not universally accepted.

Since 1987 there have been numerous industry papers, white papers from the three leading domestic battery manufacturers and others, and four (4) EPRI documents that all address ohmic measurement testing. Further discussion has appeared on websites stating the supposed “pros” and “cons” of this testing. The one that has gained the most attention among modern day users in the electric utility space is the EPRI 1002925 document. Written in 2002, it is often quoted as validation for ohmic measurement testing as a basis for determining the State of Health (SOH) of a battery string. What is overlooked is that the EPRI document states that the project only confirmed that internal ohmic measurements can only detect degraded cells. [4]

Although the EPRI document states that ohmic measurement testing can be a valuable part of a maintenance program, to wit, “These measurements reliably predicted degraded battery cells. . . . Furthermore, a high degree of correlation was demonstrated between the three types of internal ohmic measurements . . .” [5], it goes on to state “Although internal ohmic measurements can provide valuable insight into the potential presence of internal degradation, these measurements alone do not necessarily provide *absolute* verification of a battery’s capacity; only a battery capacity test can determine the total battery capacity.”[6]

In the opening paragraph of the Report Summary, the EPRI document states that while internal ohmic measurements offer a viable method of performance monitoring, these measurements demonstrate “the ability to identify degraded cells and to baseline the general health of the battery.”[7]

Finally, the EPRI study concludes, “All evaluated measurement technologies – conductance, impedance, and resistance measurements – were shown to be effective. The data scatter in these measurements limits our ability to assign a predicted value of capacity to a given cell. . . . Internal ohmic measurements are considered particularly important for VRLA batteries.” [8]

While the entire subject of using ohmic readings to determine SOH is controversial, there are some points concerning ohmic readings that most experts in the field will agree upon. First, a significant change in ohmic readings (considering that the measurement was taken properly) usually means that there is probably an issue internal to the cell that will affect capacity. Keep in mind, though, if there are minimal changes to the ohmic readings, there still can be an issue with battery performance. Finally, there is no universal definition of a 'significant change'.

The difficulty is that there is a multitude of ohmic instruments available, each with its own proprietary algorithm for measuring and calculating an ohmic value. There is no industry standard or specification for certifying an ohmic reading. The reality is that anyone can create a black box and make a claim that their instrument measures ohmic values. The term 'ohmic readings' is a generic term to encompass internal measurements of the cells as defined in IEEE 1187-2012 and confirmed by the Battery Council International.[9] This paper also states in its Recommendations/Conclusions, "Ohmic measurements are not a substitute for capacity testing and cannot be used to predict absolute capacity values."[10]

Because of the variance in equipment and the wide variance of battery types, models, chemistries and failure mechanisms, it is unwise, if not impossible to determine a universal percentage change that would equate to a battery's inability to perform as manufactured. Therefore, the burden is on the user in concert with the battery manufacturer to determine the percentage change for their particular battery using their selected ohmic device.

In order for a user to properly evaluate whether or not their station battery can perform as manufactured, they must be able to analyze the ohmic readings carefully. Simply recording and trending the readings is not sufficient. The user has to demonstrate through the evaluation of test data correlated with ohmic readings that a particular ohmic change is indicative of the threshold between being able to perform as manufactured and not being able to perform. If the user is not able to conduct this analysis, or does not have sufficient data to confirm this analysis, the best option to confirm the situation is by conducting a capacity or performance test.

There are a number of other considerations that affect the use of ohmic readings: first, a proper baseline must be established that will become the benchmark for trending results over time; second, the same testing device [and probes or clamps] should be used over the life of a particular battery string; third, technicians need to be properly trained on the use of the device being used and employ consistent monitoring techniques each time measurements are taken; and finally, results must be monitored, documented and reviewed so trend lines for proper analysis are maintained and proper corrective action can be taken.

It should be reiterated that the PRC-005-02 states 'the minimum' required maintenance. The user can certainly perform additional inspections and tests in order to meet their internal guidelines for reliability. In fact the Supplemental Guide and FAQ encourages complete battery maintenance procedures in accordance with IEEE 450, 1188, and 1106. The guide also spells out specific steps to determine when additional actions should be taken beyond simple ohmic measurement testing. Ohmic measurements can be used under this standard, but it must be clearly understood that ohmic measurements by themselves are not a true source for measuring battery string capacity until more hard data can be provided to substantiate that claim.

Finally, each functional entity that owns a Protection System must define its own meaning of true battery reliability. It is important to understand that true reliability as defined by this standard does not equate to reliable battery capacity. Each user must assess his/her own risk management tolerance and understand the consequences of failure if he/she does not perform capacity testing at all.

Conclusion

In conclusion, the proven and most effective means for maintaining lead acid and NiCad stationary batteries is to follow the recommended practices contained in IEEE 450, IEEE 1188 and IEEE 1106.

All of these standards recommend that performance testing be conducted on a periodic basis to ensure that a battery will perform as manufactured.

PRC-005-02 allows the user an alternative to performance testing for VLA and VRLA batteries. The alternative is to utilize a measured parameter or set of parameters to determine the point when the battery will no longer perform as manufactured. However, the burden of proof is on the user to provide evidence that the end of life can be reliability detected with the selected parameter(s).

If the parameter of choice is to utilize ohmic readings, the user must be aware of its limitations and accept that he/she is making a calculated risk and be willing to accept any consequences.

Finally, it is important to recognize that other parameters play an important part in maintenance of cells for optimal battery performance including visual inspections. The manufacturer's instruction set for installation and maintenance should be completely understood and followed. Documenting voltage, temperature, ohmic measurements, connection resistance, battery charger voltage measured at the battery terminals, and specific gravity and/or float current when appropriate all play a part in helping to understand a battery's state of health. Documenting trending lines and analyzing the data is vital in understanding the state of health of a battery.

And most important, the only fool proof method to determine battery health is via a capacity test.

References

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3. Ed Dobrowski, NERC Standards Development Advisor, NERC, Atlanta, Presentation to Stationary Battery Committee, Philadelphia, June 2012.

4. EPRI Document 1002925, Section 13.1, Concluding Comments, page 13-1.

5. Ibid, December 2002, Results, page vi.

6. Ibid, Section 3.4, Battery Internal Ohmic Measurement Uncertainty Considerations, page 3-5.

7. Ibid, Report Summary, page v.

8. Ibid, Section 13.7, Concluding Comments, page 13-8.

9. Battery Council International White Paper, "Recommended BCI Procedure for Ohmic Measurements as a Maintenance Tool for Lead Acid Stationary Cells, page 2 of 6.

10. Ibid, page 5 of 6