Battery Discharge Testing: Implementing NERC Standards and Field Experiences

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Abstract
Periodic testing and maintenance of battery banks is imperative to ensure reliable delivery of power when they are called upon. There are a number of different tests like: visual inspections, specific gravity, float voltage and current measurements, discharge test, individual cell condition, inter-cell resistance, and others, which are recommended in IEEE, NERC and other standards for diagnosing the condition of the battery banks. Among all the tests, the discharge test (also known as load test or capacity test) is the only test that can accurately measure the true capacity of a battery system and in turn determine the state of health of batteries.

With the approval of NERC PRC 005-2 “Protection System Maintenance“ standard, entities falling under its umbrella will have to test batteries per its requirements. The paper focus on performing the discharge test on vented lead acid station batteries using *performance* and *modified performance* test modes as per PRC 005-2 and IEEE 450 recommendations. Initial conditions, site preparation, test duration, rate of discharge, temperature effect and other key factors associated with these discharge testing modes are discussed in detail. Expected results, determination of percent battery capacity and their minimum acceptance criteria are provided.

Some less known facts like “*Coup de fouet”* phenomenon, battery derating factor and common mistakes related to temperature compensation for the time adjusted time and the rate adjusted method are discussed as well. This document shares advanced measurement techniques for continuous monitoring of individual cell voltages to predict weak cells and cell polarity reversal. It also covers maximum allowable pause time during the test to bypass the weak cells and battery replacement criteria. Field challenges associated with discharge testing are shown using a case example and user experiences.

Introduction
As the electrical grid ages and expands, it is becoming more apparent that testing and maintenance is critical to the reliability of the network. While many utilities have taken it upon themselves to develop maintenance plans, regulatory committees such as the Federal Energy Regulatory Commission (FERC) and North American Electric Reliability Corporation (NERC) have set forth mandates in order to ensure that the equipment related to protection and controls is being maintained properly. Batteries provide power to the protection and control equipment including relays, circuit breakers and other auxiliary devices. If the battery fails then the substation will be left unprotected. Due to the criticality of the batteries for protection, NERC has laid out requirements on maintaining and testing the stationary batteries. Although many tests can be performed to assess the condition of the batteries such as ohmic testing, specific gravity, state of charge etc., only the capacity test, commonly referred to as the discharge or load test, can measure the true capacity of the battery system and in turn determine the state of heath of the batteries. The capacity tests suggested by NERC standard PRC 005-2[1] are the performance test and the modified performance test. Before performing these tests, certain initial conditions must be met and a decision must be made on how to discharge the batteries. The battery may be tested to verify that the capacity is equal to or greater than the manufacturer’s specification or that it will meet the duty cycle required by the load. In the end, capacity can be determined by calculation based on a rate adjusted or time adjusted method. This paper references the IEEE 450 standard to explain different test methods, test preparation and test performance. The standard can be consulted for further details.

FERC and NERC Regulations

Blackouts have a huge economic impact on affected areas. In order to ensure a stable nationwide grid, even distribution of the bulk electric supply and more reliable power system network, independent regulatory agencies such as the FERC and NERC have been formulated in the past to monitor these activities. FERC is an independent government agency and its goal is to assist consumers in obtaining reliable, efficient and sustainable energy services at a reasonable cost through appropriate regulatory and market means. NERC is a self-regulatory organization whose mission is to ensure the reliability of the North American bulk power system. It is subjected to oversight by the FERC. NERC has the legal authority to enforce reliability standards with all users, owners, and operators of the bulk power system in the United States and Canada.

The existing NERC reliability standard that applies to battery testing and maintenance is "Standard PRC-005-2 – Protection System Maintenance". The purpose of this standard is to ensure that all protection systems affecting the reliability of the Bulk Electric System (BES) are maintained, tested and kept in working order. It is applicable to all generation owners, transmission owners and distribution providers. NERC's PRC 005-2 standard provides recommendations for maintaining, testing and recording data for the stationary batteries. In the standard, Table 1-4 (a)[1] lists the testing and maintenance intervals for vented lead acid batteries. Key maintenance activities recommended in the table are listed below:

- Every four months, verify station DC supply voltage and check the electrolyte level and any unintentional grounds.
- Every eighteen months, check float voltage, internal ohmic value, inter-cell connection resistance and battery rack structure.
- Perform internal ohmic test and compare against baseline once every 18 months OR verify that the station battery can perform as manufactured by conducting a *performance* or *modified performance* capacity test of the entire battery bank at least once every 6 years.[1]

Performance Test

A performance test is defined as "a constant-current or constant-power capacity test made on a battery after it has been in service"[2]. It is the most commonly used discharge test method and it determines if the battery is performing according to the manufacturer's specifications and/or if it is within acceptable limits. It can be used for benchmark as well as maintenance practices. For the performance test, a constant current method is generally used where a constant current specified by the manufacturer is applied for an accompanying specified time. Battery manufacturers publish tables that include different discharge rates specified for different periods of time. Each discharge rating has an end point cell voltage that is used as the stop criteria for the discharge test. The user in the field, depending on the load requirements, amount of time available or the capabilities of the test equipment can determine the appropriate discharge rate. The measured capacity is generally corrected to 25 ^{o}C but temperature correction can vary by manufacturer. It is recommended that this test be performed within the first two years after the battery has been put in service[2]. Thereafter, the test interval should be at 25% of the expected service life. It should be performed annually if the battery shows any sign of degradation or has reached 85% of the service life expected for the application[2]. However, if the battery has reached 85% of service life but delivers a capacity of 100% or greater of the manufacturer's rated capacity, and has shown no signs of degradation, performance testing at two-year intervals is acceptable[2].

Modified Performance Test

A modified performance test is defined as "a test, in the "as found" condition, of battery capacity and the ability of the battery to satisfy the duty cycle"[2]. The modified performance test is similar to the performance test in that it verifies manufacturer's specifications and tests the capacity of the battery, it also has the added benefit of verifying that the battery will meet the specified duty cycle. The test is designed to encompass the entire duty cycle so a chosen current is applied for a certain amount of time and then "modified" and applied for a different amount of time. This is repeated until the entire duty cycle is completed. Once the duty cycle is satisfied, the remainder of the test is dedicated to meeting the manufacturer's specifications while taking into account the aging margin.

There are three types of modified performance tests[2]. For trending purposes once one type of test is used the same type should be used for the remainder of the battery life. For a type 1 and type 2 modified performance tests the duty cycle is multiplied by the aging margin in order to determine the minimum test duration. If IEEE 485 was followed to determine the size of the battery then an aging factor of 1.25 should be used[3].

Type 1 modified performance test[2]:

A type 1 test is used when the duty cycle encompasses a very large load for a short amount of time (T1), typically one minute, followed by a reduced load for an extended amount of time (T2). A situation like this can arise when a serious fault occurs in the electrical system and a lot of current is required from the batteries by the switching equipment to clear the fault. Once cleared, the station will then require DC power to maintain operations until it is back online.

To perform a type 1 test, first determine the initial current required, either by the maximum load the battery will see for the duty cycle or by the manufacturer's one minute rate divided by the aging factor. For the remainder of the test, use the manufacturer's published discharge rate for the time period specified by the entire duty cycle multiplied by the aging factor used in sizing the battery. The discharge test is started with the high current rate and when T1 is reached, the voltage at the battery terminals is recorded. Reduce the current to the second rate and proceed with the discharge test.

Type 2 modified performance test[2]:

A type 2 modified performance test is used when the duty cycle is more complex. For this type, all currents above the standard performance test are measured and the remaining duty cycle is modified. The test time can be calculated by multiplying the battery's total duty cycle time with the aging factor. With this calculated test time, the corresponding recommended discharge current and total capacity is obtained from manufacturer's specifications. Any current in the duty cycle that is greater than the manufacturer's specified current should be discharged for the time required by the duty cycle. The total amp hours (capacity) removed for this portion of the test is then subtracted from 80% of the manufacturer's specified capacity. The capacity remaining is then divided by the time remaining to determine what current is used for the remainder of the test. This constant current is then discharged for the remainder of the test. If the end voltage is not reached after this time, the amperage is returned to the manufacturer's recommended discharge rate for the initial age adjusted time. Proceed with this current until the end voltage is reached.

Type 3 modified performance test[2]:

With the type 3 test, a service test can be performed to test the battery in the "as found" condition and cover the entire duty cycle. The discharge test is started without equalizing the battery and performed to satisfy the battery's duty cycle. Once the duty cycle is met, the remainder of the test is carried out according to the standard performance test discharge method.

A detailed description of any of the modified performance tests, and case examples can be found in IEEE 450 Annex I.

Effect of Temperature

Cell temperature can greatly affect the battery's performance. It can affect both the state of charge and state of health of the battery. Batteries perform best when they are operated at or close to their published rated temperature. At higher temperatures, the internal resistance of the cell goes down, accelerating the rate of chemical reaction and thereby improving the capacity of the battery. However, operating the battery at elevated temperature reduces the service life of the battery. Conversely, at colder temperatures, the chemical reaction rate slows down and the capacity decreases[4]. Manufacturer's recommend operating the battery at published temperature to derive the published capacity and optimize the service life of a battery. When a capacity test is performed at any temperature other than the manufacturer specified temperature, correction factors are applied (per IEEE 450 or manufacturer recommendations) to capacity calculations for baseline comparison and trending of results.

Battery Derating Factor

Batteries are sized to serve the designed load requirements throughout its expected service life. Like any other electrical asset, battery performance deteriorates with age, temperature, charge-discharge cycles, maintenance practices, charger settings and a number of other factors. Batteries are therefore sized with an aging factor so that they can deliver a charge to the specified load till the end of their life cycle. Aging factor is the safety margin built into the sizing calculation when selecting the battery's rated capacity[3]. The derating factor is based upon the aging factor. It is indicative of reduced capacity as the battery approaches the end of its service life[2]. A battery sized with an aging factor of 1.11 will have a derating factor of 0.9. In this case, a battery having 90% published capacity remaining will marginally meet specified load requirements with no safety factor. It also shows the end of the battery's service life where any further decrement in capacity would put the system at risk.

Capacity Calculation Methods

A battery's capacity is shown in amp hours. It is typically expressed as a percentage, as a ratio of measured amp hour capacity to manufacturer's published capacity (rate x time). There are two different methods that can be used to determine the capacity of a battery bank.

Time adjusted method:

In the time adjusted method, the test current is kept constant and is defined by the published rate (discharge current) for the desired time duration[2].

Table 1: Manufactured published ratings at 25 C

Constant Current Discharge Ratings – Amperes @ 77°F (25°C)

Operating Time to End Point Voltage (in hours)

End Point Volts/Cell	.083	.25	.50	.75	1	2	3	5	8	10	12	20	24	72	100
1.90	230	170	116	90	72.5	41.5	30.7	20.2	13.4	11.0	9.4	6.00	5.08	1.82	1.32
1.85	260	185	128	99	79.0	44.0	32.5	21.8	14.5	11.9	10.1	6.39	5.40	1.92	1.40
1.80	310	205	136	103	82.5	47.3	34.7	22.7	15.2	12.4	10.6	6.60	5.58	1.97	1.43
1.75	371	228	146	111	88.0	49.0	36.0	23.6	15.8	12.8	10.8	6.74	5.68	2.01	1.46

The capacity test is performed until the voltage reaches the end cell terminal voltage. In Table 1 above, for a 1.75 V end cell voltage and an 8 hour test, the rate will be 15.8 A. Since the rate is kept constant and equal to published rate, battery capacity is calculated as the ratio of measured discharge time to published discharge time.

$$\% \, C = \frac{(Ta \times 100)}{(Tm \times Kt)}$$

Where,
C= Capacity at 25 ^{o}C
Ta= Actual time duration of test to specified terminal voltage
Tm= Published rated time to reach terminal voltage
Kt = Temperature correction factor as per IEEE 450 Table (1)

Rate adjusted method:

The rate adjusted method is more complex than the time adjusted method. In this method, time duration is kept constant and the rate is adjusted based upon the battery's derating factor[2]. IEEE 485 states that "*To ensure that the battery is capable of meeting its design loads throughout its service life, the battery's rated capacity should be at least 125% (1.25 aging factor) of the load expected at the end of its service life.*"[3] This means the battery would reach the end of its service life when it reaches 80% of its specified performance.

Based upon this, from Table 1, for a 15 min test duration and a derating factor of 0.8, the rate is adjusted to 182 A (80% of 228 A). The test is conducted with 15 minute and 182 A settings until the specified end voltage is reached. Capacity is calculated by taking ratio of test rate and published rate corresponding to *actual* test duration using manufacturer's data.

$$\% \, C = \frac{(Xa \times Kc) \times 100}{Xt}$$

Where,
C= Capacity at 25 ^{o}C
Xa= Actual rate used for the test
Kc= Temperature correction factor as per IEEE 450 Table (2)
Xt= Published rating for time to specified terminal voltage

This method can be difficult to use because the discharge rate corresponding to *actual* test time sometimes is not available in manufacturer published data and in some cases, interpolation and some other curve fitting techniques are used to determine it.

Two factors that affect the capacity calculation numbers are degradation in battery quality and reduction in battery efficiency at high discharge rates. It is a well known fact that battery efficiency decreases with increased discharge rate. The capacity measured at the 1 hour discharge rate is different from the capacity measured with an 8 hour discharge rate. The time adjusted method provides a conservative end of life assessment because it does not take into account changes in battery efficiency with discharge time[2]. Technically, the rate adjusted method provides more realistic results as it takes into account the battery sizing criteria and derating factor. That is why, when high rate short duration tests are performed, the rate adjusted method yields more accurate results than the time adjusted method[2]. Both test methods yield the same results when tested for long durations (typically 8 hours). Because of simplicity, it is recommended to use the time adjusted method for long duration tests (i.e. 60 minutes or greater). The rate adjusted method, though complex, is preferred when performing a short duration (i.e. 60 minutes or less) high discharge test because results will not be masked by the battery efficiency factor[5].

Coup De Fouet

A fully charged lead acid battery when subjected to discharge testing typically shows a phenomenon at the beginning of test known as *coup de fouet*. It is a dip in voltage from initial float voltage conditions to a lower voltage during the initial few seconds/minutes of discharge testing, followed by a recovery of the voltage to a stable level (plateau voltage)[6]. The drop in voltage and final recovery voltage will vary based upon the design and age of the battery, discharge rate, temperature, float voltage and other operating conditions. The low end point voltage in the *coup de fouet* region is referred to as the trough voltage.

Many research papers have shown a correlation between the State of Health (SoH) of batteries and the voltage drop from float condition to trough voltage. Batteries with lower SoH would show a higher voltage drop and those with higher SoH would show lesser voltage drop in the *coup de fouet* region[6]. This voltage drop corresponds to the loss of capacity of the battery under discharge testing. Additionally, other papers showed results that higher discharge rates or lower operating temperatures result in increased voltage drop. This observation fits well with reduced capacity at higher discharge rates and lower operating temperatures[7]. Conversely, reduced voltage drop will be observed at lower discharge rates or higher temperatures. With the ageing of the battery, this voltage drop would increase, indicating a reduction in battery capacity. The correlation between coup de fouet region voltage drop and SoH can vary with cell type, test conditions and various other factors. Further studies need to be done to establish a direct correlation between the two and at present it can only be used for rough approximation of SoH.

Site Preparation

Site preparation is important to ensure that testing is performed safely and correctly. Before performance or modified performance testing can begin, certain initial conditions need to be met. The load connected to the battery should be connected to backup power prior to disconnecting the bank for testing. The minimum PPE required is goggles and face shields, acid-resistant gloves, and a protective apron. Additionally, safety guidelines recommended by IEEE 450 as well as federal, state, and local safety precautions should be followed.

Since the pre-test conditions can greatly affect the outcome of the test; it is recommended to check some key parameters before initiating the test. Prior to testing, the battery should be under float conditions for at least 72 hours[2]. Individual cell voltage, float current from the charger and battery terminal float voltage should be measured to verify the float conditions[2]. Stabilized float current measurement can be used to determine the fully charged state of the battery. The battery connections and resistance measurements should be checked. Additionally, the temperature of the electrolyte in 10% or more of the cells should be measured[2]. Make sure the battery is isolated from any other battery or critical load. Once all initial conditions are met, the load bank and any other necessary test equipment should be setup, the battery should be disconnected from the charger and connected to the load bank. If it is not possible to disconnect the charger, the load should be adjusted to compensate for the current that the charger is providing.

Discharge Test Process

After the initial preparation, the discharge rate and test duration is selected using manufacturer's published data. These test parameters will be dependent on the selected test and on the method used for capacity calculations. It should also be noted that current values are not adjusted for temperature; temperature is taken into consideration when the capacity is calculated. Timing starts when the load begins to discharge the battery at the determined discharge rate. The battery should be discharged until it reaches minimum terminal voltage. The minimum terminal voltage is determined by multiplying the number of cells to the minimum average voltage of the cell that is specified by the design. A minimum of three measurements of both the battery terminal voltage and individual cell voltages should be measured over the course of the discharge; one immediately at the beginning of the test when the load is applied (to detect any initial voltage drop due to application of the load), one or more at specified intervals, and one at the end of the test[2]. In order to include the voltage drop across the intercell connectors, the voltage of each individual cell should be measured from posts of the same polarity from one cell to an adjacent cell[2].

Figure 1 shows battery voltage monitors connected to the cells that monitor individual cell voltage and overall terminal voltage at specified intervals for the duration of the test. While the test is being performed, the connectors between the cells should be monitored for any abnormal heating. It is allowed to pause the discharge test for up to 10% of the total test time, or six minutes, whichever is shorter[2]. This is to allow the user to fix any problems that might arise during the test, e.g. bypass an individual weak cell or to fix any problem with the connections or test equipment. Only one pause is allowed for the duration of the test and the pause time should not be counted in the total discharge time[2]. Once the test is completed, determine the battery capacity. The test equipment can then be disconnected.

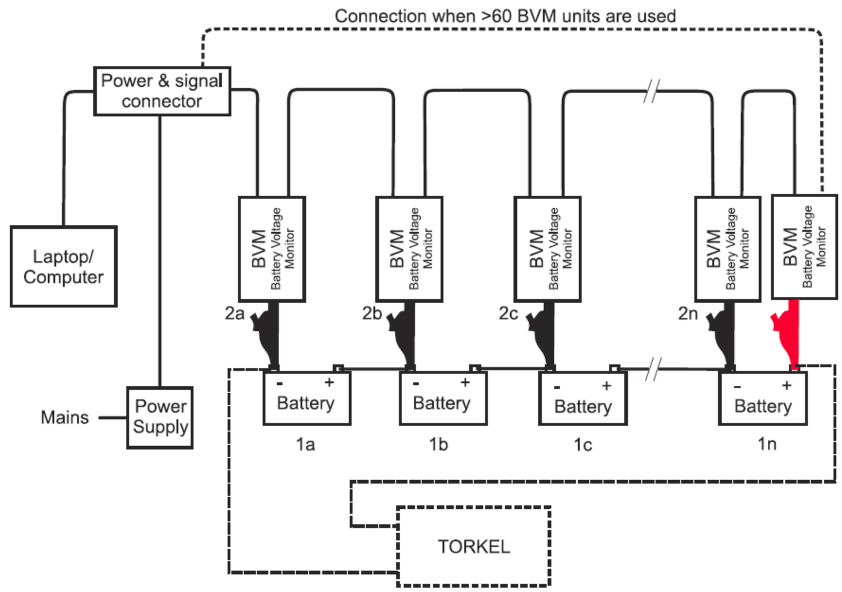

Figure 1: Connection of individual voltage monitors and load bank for discharge testing

Cell Bypass and Polarity Reversal

While performing the discharge test, one should be prepared to bypass weak cells approaching polarity reversal. Polarity reversal takes place when one or more than one cell is weaker than the other cells in the string. Since, all the cells are in series and the discharge current is the same, the weak cells tend to overheat and discharge faster than the others. This can bring the whole battery string down. If any cell voltage drops to 1 V or below, they are considered to be approaching polarity reversal. In the event of polarity reversal, it is recommended to pause the test, disconnect the weak cell, and bypass it with a jumper suitable to handle the discharge test current[2]. All safety and precautionary measures should be followed when performing this. The end voltage should be recalculated and test should be resumed with a modified end terminal voltage. The maximum allowed time to bypass a weak cell and then resume the test is defined by the lesser of 10% of test time duration or six minutes[2]. Only one pause is allowed for the duration of the test. Pause time should not be counted in total discharge time. If cell reversal is identified at the very end of the discharge testing, it is recommended to finish the test and not take any action. Bypassing of weak cells is not allowed during the duty cycle portion of a modified performance test[2].

Battery Replacement Criteria

At the completion of a capacity test, the measured capacity should be reviewed based upon sizing criteria used during installation to determine if the battery is still able to meet the load requirements. The most recommended practice is to replace the battery bank if measured capacity is less than 80% of manufacturer published ratings[2]. The replacement should be made as soon as possible, without exceeding one year from the date of the capacity test. When looking for a replacement, it is recommended to follow the IEEE 485 guidelines to perform the sizing calculations and contact the battery manufacturer for recommendations on the appropriate battery style and design to meet the requirements. A new capacity baseline for the replacement bank should be established by performing an acceptance test on site as per IEEE guidelines.

In the event that only one or a few cells need replacement, the battery manufacturer should be consulted on compatibility with the existing battery installation, overall duty cycle and load requirements. Efforts should be made to identify replacement cells that have similar performance characteristics to the existing installation. All replacement cells should be tested for capacity as per the IEEE acceptance criteria before replacement. After the replacement, benchmark capacity of the battery bank should be re-established using either the time adjusted or the rate adjusted method[2].

Discharge Test Example and Results

The discharge test was performed on a battery bank with 56 cells and 112 V (2 Volts/cell) installed in Jan 2003. Its published ratings are shown in Table 2.

Table 2: Manufactured published discharge ratings at 20 C

Constant Current Discharge in A/cell (at 20 °C)													
	Discharge Time												
Uend	15 min	30 min	45 min	1 h	1.5 h	2 h	3 h	4 h	5 h	6 h	8 h	10 h	20 h
1.60 V	416.2	296.2	237.3	202.7	158.4	131.3	100.5	81.7	69.1	60.2	48.6	41.0	22.7
1.65 V	383.3	282.6	229.5	197.9	155.5	129.2	99.2	80.7	68.3	59.6	48.1	40.7	22.6
1.70 V	345.4	262.4	217.4	190.3	151.2	126.3	97.3	79.4	67.3	58.7	47.5	40.2	22.3
1.75 V	296.5	238.2	202.2	180.1	146.1	123.1	95.1	78.2	66.5	57.9	46.8	39.7	22.0
1.80 V	249.0	208.1	179.2	161.1	134.0	115.1	91.2	75.6	64.7	56.6	45.8	38.7	21.6
1.83 V	218.3	185.4	162.5	148.0	124.0	108.0	87.0	72.4	62.4	54.7	44.3	37.3	20.8

The average cell temperature measured was 20 °C. A *performance test* was conducted at a constant discharge current of 95.1 A for a 3 hour time duration using the time adjusted method. The end cell voltage per the published rating was 1.75 V per cell. A Torkel 840 load bank along with 57 Battery Voltage Monitors (BVM's) was used to perform the discharge test as shown in Figure 2.

Figure 2: Connection of BVM's and load bank to the battery

The discharge test was conducted at a constant current and the battery terminal voltage was measured as a function of time for the test duration as shown below in Figure 3.

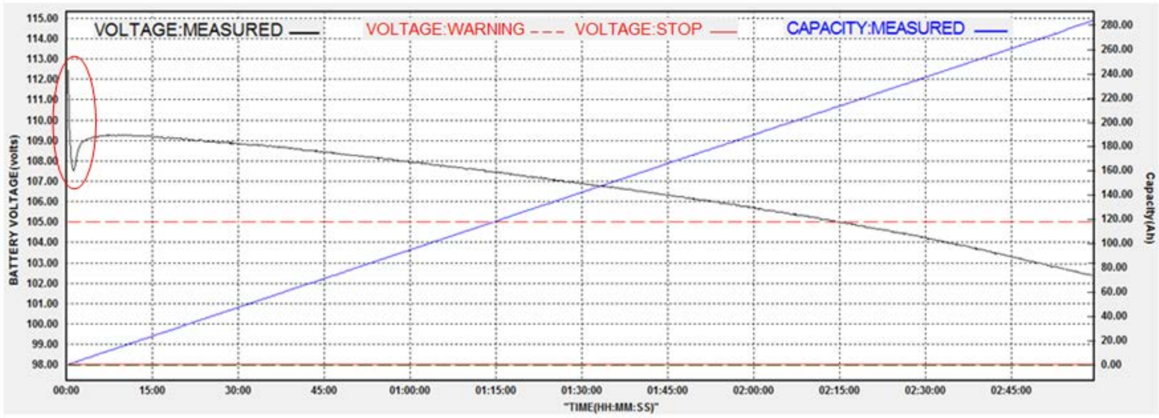

Figure 3: Measured battery voltage as a function of time for discharge test

The *coup de fouet* phenomenon observed in the battery terminal voltage at the start of the test (circled in Figure 3) is common for vented lead acid batteries. The test was scheduled for duration of 3 hours. Upon reaching 3 hours, it was decided to stop the test due to time and site constraints. Individual cell voltages were monitored and the comparison of initial voltage to final voltage of each cell is shown below in Figure 4.

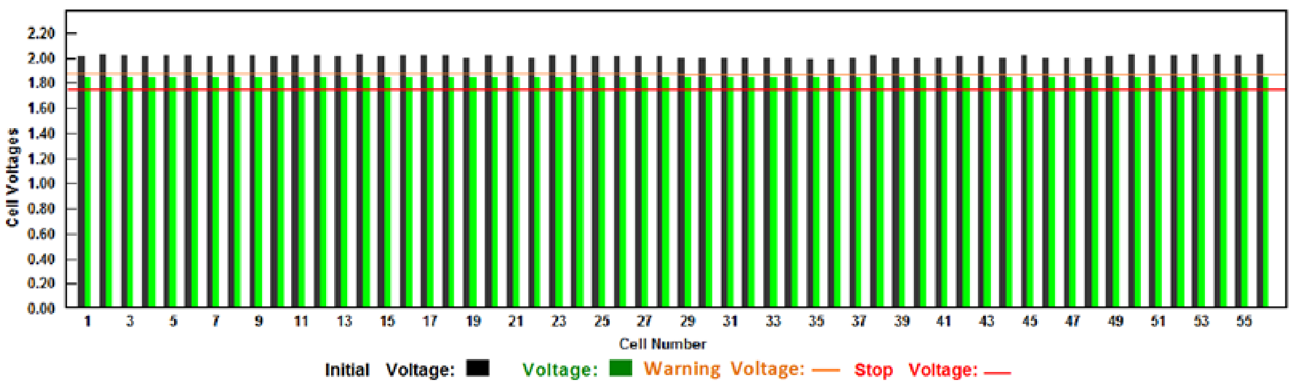

Figure 4: Initial and final voltage of each cell with warning and stop limits

Figure 5 below shows that prior to running the test and turning off the charger, the batteries were in open circuit condition with a voltage slightly higher than 2 V. When the charger was disconnected and the test was initiated, it resulted in a drop of voltage, followed by an increase to plateau voltage and then a gradual decrease in voltage for the rest of the test duration. Upon test completion, there was an expected increase in the voltage of each cell due to the load bank being removed. All cell voltages were monitored; Figure 5 below shows the performance of a few cells during the discharge test.

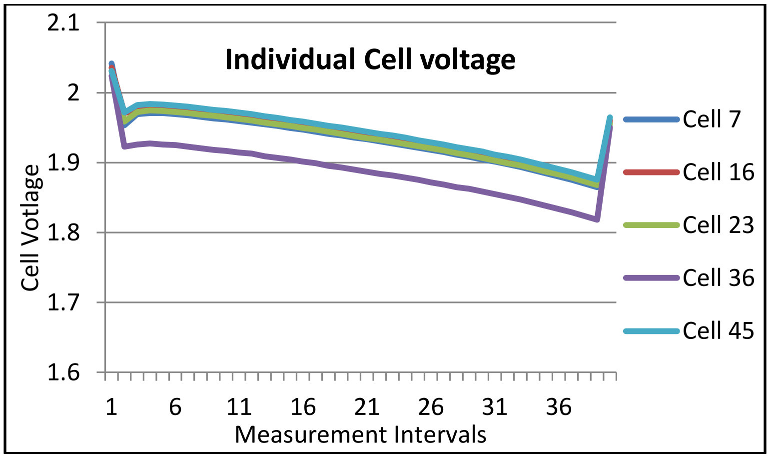

Figure 5: Voltage response of individual cells during the test

The available capacity of a cell or bank is affected by its operating temperature and capacity is usually defined for 25 ^{o}C. As per IEEE 450, for the above field example, a correction factor of 0.977 should be applied to compensate for the temperature. However, the published ratings for the battery under test were specified at 20 ^{o}C. In this case, the average electrolyte cell temperature measured was 20 ^{o}C; therefore a correction factor of 1 was used. If the measured temperature was not 20 ^{o}C, correction factors from the battery manufacturer should have been used instead of the IEEE recommended correction factors. Battery capacity calculation was performed using the time adjusted method:

$$\%\,Capacity = \frac{Measured\ Time}{(Published\ Time\ \times\ Temperature\ Correction\ Factor)} = \frac{3}{(3\ \times 1)} = 100\ \%$$

The capacity of the battery bank came out to be 100 % using the time adjusted method. As noted above, the discharge test was stopped at 3 hours and at that time individual cell voltages were still above end cell voltage limit, therefore actual battery capacity is higher than the calculated capacity of 100%. The results showed that the batteries are in very good condition. None of the cells showed any problems.

Field Challenges Associated With Discharge Testing

Load selection for discharge test

Battery manufacturer's published discharge times range from 1 to 20 hours or more. It is preferred to test the batteries in a reasonable amount of time. A performance test with time duration of 3 to 4 hours is common; however shorter test times require higher loads. The discharge current required for these short duration tests can exceed the nominal capacity of portable instruments. This problem can be solved by connecting additional load units in parallel. Advanced planning is needed if extra units are required to achieve the desired discharge rate and time frame assigned for the activity. In any case, no matter how big the load is, power is dissipated in the instrument as heat during the test. Care should be taken to direct the heat dissipation away from the batteries and/or properly ventilate the area to avoid heating the room or batteries while testing. Also, if several units are to be connected in parallel, there might not be enough space at the end posts to connect the cables from the load units. A good practice is to have a piece of cable or bar available to extend the post a little and provide space to connect the cables from multiple load banks.

Backup power

Backup power can be provided by means of a mobile DC power system or through a backup battery bank at the substation. In cases where no backup power is available, an on-line discharge test can be performed. In this type of test, the regular substation load is always connected to the battery during the test and is continuously monitored. The load bank maintains the desired constant current by regulating the remaining current needed in addition to the substation load current. This method requires an additional CT accessory to monitor the substation load current.

Connection to insulated posts

Some batteries might have the post and the straps totally insulated with just a small access to measure the voltage with a digital voltmeter. This could make the installation of the load cables and especially the individual voltage monitors very difficult. The batteries should be prepared for the connections; several different types of clips or leads should be available to connect the individual voltage monitors to the batteries.

Bypass a cell

Bypassing a cell might be required during the test. If a cell hits 1 V or less, it should be bypassed. The time allowed by the IEEE 450 standard for bypassing a cell is very short. It is a simple procedure but it requires being ready with a bypass cable of the right gauge and length. Check historic tests to determine if a bypass might be required and prepare the proper cable for it. Insulated tools should be available for this procedure to avoid a short circuit during the cell bypass.

Summary

With regulations set forth by NERC and FERC all generation and transmission owners as well as distribution providers must be compliant or they will face heavy penalties imposed by these regulatory agencies. Maintenance must not only be performed but well documented. Test results and maintenance records must be provided to NERC upon request. In addition to being one of the options under compliance tests, the capacity test determines the true health of a battery. Safety precautions should be taken and certain initial conditions need to be met before the capacity test can be performed. A performance test is used to verify the battery's capacity related to the manufacturer's specifications. The modified performance test will also verify that the battery meets the specified capacity but in addition, it will test the duty cycle required by the load. The test method should be determined prior to testing and the same method should be repeated for the remainder of the battery life. The capacity can be calculated using the time adjusted or the rate adjusted method. The effect of temperature is taken into account by utilizing temperature correction factors during the capacity calculations.

Proper maintenance will not only ensure that the battery owners are compliant but also determine the health of the batteries. The capacity test will help owners to verify that the battery will supply the load needed when called upon to protect valuable assets. Additionally, it helps in scheduling replacements when the battery starts to approach the end of its service life.

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