Substation Battery & Charger Maintenance

1.0 Introduction

Storage batteries are used to supply stored energy for operation of substation protective relaying and controls. They are kept at a fully charged level by self-regulated battery chargers that are set to maintain a specific DC bus voltage. The battery charger can never be relied upon to supply DC current for operating any protection equipment. This is due to the fact that the fault can easily depress the charger supply voltage to the point that the charger stops functioning. Failure of the battery to perform its intended function can result in local service interruption, significant damage to substation equipment and in some cases widespread outages or major system disturbances. Not having adequate battery capacity available at all times is equivalent to removing relay protection and should be approached with extreme caution. If in the highly unusual situation where the battery supply must be disconnected in an energized station, and time is not of the essence, obtain permission from the supervisor. Prompt attention to any abnormal situation involving DC systems is essential and maintenance related to batteries and chargers should be of the highest priority.

2.0 Related Documents

MNT-TRMX-00001
MNT-TRMX-00060
JPL-TRMX-03000
JPL-TRMX-03010
JPL-TRMX-03020
BAS-TRMX-03000
REG-TRMC-00001
REG-TRMF-00002
3.0 Scope

This procedure defines checks, tests, and settings that are necessary for proper maintenance of storage batteries and battery chargers. There are multiple tests and checks that help preserve life and determine the condition of batteries including periodic cell voltage and gravity readings as well as cell impedance measurements. Battery condition can be determined based on all of the testing results along with the condition of the hardware that make up the complete battery system.

4.0 Safety & Environment

When performing battery maintenance, eye wash solution shall be readily available. Battery rooms should be well ventilated. Use bicarbonate of soda solution, 1.0 lb bicarbonate of soda to 1 gallon of water, to neutralize acid spillage. Batteries are heavy and proper lifting techniques should be employed. Much of the battery work is done upstream of any protective breakers or fuses so extreme care should be taken to avoid short circuiting a single cell or battery set. Keep tools insulated. For the protection of our employees and the environment, employees should stay abreast of and adhere to all safety rules, established work practices, and environmental compliance practices while performing maintenance on this equipment.

5.0 General Information

5.1 Factors That Will Require Attention and Resolution

- Specific gravity reading in a cell or battery out of range.
- A specific cell or battery requiring an excess amount of water to be added.
- Problems with similar batteries in service that are reported by company personnel or the manufacturer.
- Cell or battery voltage reading out of range.

5.2 Records

- Inspections and maintenance performed to be recorded on appropriate job plan and retained in accordance with REG-TRMC-00001 or REG-TRMF-00002.
- Battery impedance test and connector resistance test to be recorded and retained in accordance with REG-TRMC-00001 or REG-TRMF-00002. This is usually downloadable from the test equipment software.
- Include the name of the tester and date of test on all records.
5.3 Special Equipment Required

- Hydrometer, battery thermometer, distilled water, funnel, battery grease, impedance test set, baking soda.

6.0 Battery Visual Inspection

6.1 Verify that battery box is in good condition

- Inspect the locks, lid, hinges, cable supports and rails to be in good condition. Repair as necessary.
- Inspect any fuse blocks, fuses and cables for corrosion, loose connections and deteriorated fuse barrels. Repair as necessary.

6.2 Verify that battery room and rack is in good condition.

- Inspect the room to be clean and free of peeling paint. Clean and repair as necessary.
- Inspect the room lighting and ventilation to be functioning correctly. Clean and repair as necessary.
- Inspect the rack to be clean, free of corrosion, stable and able to support the battery weight. Clean and repair as necessary.

6.3 Battery Physical Condition Inspection

- Inspect battery to be clean, case has no cracks, no leaks and tops are dry and not lifting. Clean and repair as necessary.
- For clear cases inspect the plates for warping and excessive sedimentation. Document any abnormal conditions.
- Inspect battery straps to be free of corrosion. Clean and repair as necessary. Note: Strap repair replacement is Relay responsibility for Carolinas and Substation Electrician responsibility for Florida. For batteries with two-hole post, the two straps should be installed one above the other on separate bolts. This allows one strap to be removed at a time for cleaning or replacement without interrupting the DC supply.
- Inspect battery terminal connections to be free of corrosion. Clean and repair as necessary. Note: Terminal repair replacement is Relay responsibility for Carolinas and Substation Electrician responsibility for Florida.
- Coat all cleaned or replacement connectors, posts, and hardware with a thin film of no-oxide grease.
- Torque all battery connections to 70 inch-pounds unless manufacturer specifically requires a different torque value.

7.0 Battery Electrical Condition Measurements

7.1 Battery Specific Gravity Checks

- Read and record the specific gravity of all cells. Check specific gravity before adding water. Refer to manufacture’s literature for specific gravity values. If cell specific gravity values are not within the proper range correct as necessary. If manufacturer’s recommended values are not known then the acceptable values for fully charged lead acid batteries are 1.210 – 1.300.

- Read and record pilot cell temperature. Add .001 to gravity readings for each 3ºF above 77ºF. Subtract .001 from gravity readings for each 3ºF below 77ºF.

7.2 Battery Voltage Checks

- Read and record cell voltages. Refer to manufacturer’s literature for correct cell voltages. Be aware that float voltages vary per lead-alloy composition (for example: lead-antimony vs. lead-calcium), per manufacturer, and per electrolyte composition (SG). If manufacturer’s recommended values are not known then the acceptable open circuit voltages for fully charged lead acid batteries are 2.05 – 2.15 VDC. If cell voltages are not within the proper range correct as necessary. The open circuit voltage and specific gravity are related by the formula below.

\[
\text{OCV} = \text{S.G.} + 0.845
\]

7.3 Float Voltage Levels

- Acceptable voltage values for fully charged lead acid batteries

<table>
<thead>
<tr>
<th></th>
<th>1-cell</th>
<th>24-cell</th>
<th>60-cell</th>
</tr>
</thead>
<tbody>
<tr>
<td>lead-antimony</td>
<td>2.15 - 2.17</td>
<td>51.6 - 52</td>
<td>129 - 130</td>
</tr>
<tr>
<td>lead-calcium</td>
<td>2.2 - 2.3</td>
<td>52.8 - 55.2</td>
<td>132 - 138</td>
</tr>
<tr>
<td>re-combination*</td>
<td>2.27</td>
<td>54.5</td>
<td>136.2</td>
</tr>
<tr>
<td>lead selenium</td>
<td>2.25</td>
<td>54.0</td>
<td>135.0</td>
</tr>
</tbody>
</table>

*re-combination battery must never exceed 2.4 v/cell
7.4 Equalize Voltage Levels

- Acceptable voltage values for fully charged lead acid batteries

<table>
<thead>
<tr>
<th></th>
<th>1-cell</th>
<th>24-cell</th>
<th>60-cell</th>
</tr>
</thead>
<tbody>
<tr>
<td>lead-antimony</td>
<td>2.33 - 2.35</td>
<td>56 - 56.5</td>
<td>140 - 141</td>
</tr>
<tr>
<td>lead-calcium</td>
<td>2.33 - 2.35</td>
<td>56 - 56.5</td>
<td>140 - 141</td>
</tr>
<tr>
<td>re-combination*</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>lead selenium</td>
<td>2.35</td>
<td>56.4</td>
<td>141.0</td>
</tr>
</tbody>
</table>

*re-combination battery must never exceed 2.4 v/cell

7.5 Battery Impedance Test

- Measure and record the internal impedance of each battery cell along with the ambient and cell temperatures. The battery should be fully charged and being kept at the float voltage by the charger.

- The internal impedance of each cell should be within ± 20% of the average of all cells. Notify supervisor to determine if cell or cells should be replaced.

- Deteriorating cells are identified by their higher than average impedance.

7.6 Connector Resistance

- Measure and record the resistance of the terminal connections and inter-cell connectors.

- Measured values should be ≤ 0.1 milli-ohm.

- Torque and/or clean connections or replace strap when resistance reading is abnormal.

- Coat all cleaned or replacement connectors, posts, and hardware with a thin film of no-oxide grease.

7.7 Battery Capacity Test (nuclear facilities only) Per NEIL STANDARD 14.C.3

Initially within the first two years of installation, then every five years until 85% of service life or signs of degradation (see IEEE 450-1995) occur, then annually. Replace battery if capacity is less than 80% of manufacturer's nameplate. Replacement shall be made within one year.

Battery capacity testing is not part of PE's NERC battery maintenance program but is a requirement of the insurance carrier Nuclear Electric Insurance Limited (NEIL).
8.0 Charger

- Perform visual and mechanical inspection of the charger to ensure all wiring and components are in good condition and electrical connections are tight.
- Set float and equalize levels as per 6.2 and 6.3.
- Set current limiter to maximum of 140 percent of charger rated DC current.
- Check operation of electromechanical equalize timer. Verify that the equalize charging is stopped before the timer motor is turned off.
- Verify that the charger is labeled with the correct float voltage.
- Verify correct reading of volt and ammeter.
- Check DC ripple voltage on chargers with filtering sections. Ripple should be 30 milli-volts or less.

9.0 Battery Alarm

- Set under voltage alarm to 50 volts on 48 volt system and 125 volts on 125 volt system.
- Check operation of local and remote alarm as applicable.
- If applicable, verify DC voltage reading at the Energy Control center is correct.

10.0 General Checks

- Read and record charger current and float voltage.
- Read and record equalize current and voltage. This is not necessary if battery manufacturer states that the specific model of battery does not require an equalizing charge.
- Check DC system for grounds. Repair or report as necessary.
- Add distilled water to bring cell electrolyte levels to the max fill line. Clean tops of batteries with distilled water after reinstalling caps; wipe down with damp cloth. Leave battery tops dry.
- Inspect any main DC distribution panels and fuses. Verify that fuses are not warped, bulged, loose or corroded.
- Inspect any main DC distribution molded case circuit breakers and connections that are accessible. It is not intended that panel fronts be removed.
11.0 TERMS AND DEFINITIONS

Acceptance Test: A constant-current capacity test made on a new battery to determine that it meets the manufacturer’s rating.

Ampere-Hour (Ah) Capacity: Rated capacity in Ampere-hour (or Watt-Hour) assigned by the manufacturer for a given discharge time at a specified electrolyte temperature and specific gravity to a given end of discharge voltage. It indicates the ability to supply a given current for a given period of time at a given temperature while maintaining voltage above a given minimum value. Most Ampere-Hour (Ah) nominal ratings of stationary battery cells for utility applications are specified with an 8-hour discharge rate to 1.75 volts per cell (vpc). Refer to manufacturer’s discharge rate tables for ampere values at various periods of time.

Capacity Test: A discharge of a battery to a designated terminal voltage. See acceptance test and performance test.

Electrolyte: The conducting medium, in which the electricity flows within the cell of a battery, and which supports the chemical reactions required. Electrolyte in lead-acid battery cells is a dilute solution of sulfuric acid and water.

Equalizing voltage: The voltage, higher than float, applied to a battery to correct inequalities among battery cells (voltage or specific gravity).

Flame Arrestor: This is a porous filter grayish in color normally located on top of vented lead acid cell jars. It allows for filling the cell with water and prevents external sparks or flames from igniting internal cell gases.

Float voltage: The voltage applied to a battery to maintain it in a fully charged condition during normal operation.

Flooded Cell: A cell in which the products of electrolysis and evaporation are allowed to escape to the atmosphere as they are generated. These batteries are also referred to as “vented.” See Vented Lead Acid Cell.

Individual Cell Voltage (ICV): The voltage measured across one cell in a multi-celled battery.

Inter-cell Connection Resistance: The total electrical resistance of the connection between the terminals of two cells that are electrically connected to each other. It includes the resistance of the connector and the contact resistance at the point(s) of connection to the cell terminals.
Lead Acid Cell: A cell in which the electrodes are made of lead and the electrolyte is a solution of sulfuric acid in water. Lead-acid cells include pure lead cells (also called Planté plate cells) and lead alloy cells such as lead-antimony, lead-calcium, lead-selenium, etc.

Lead-Antimony Cell: A lead-acid cell with plates or grids made from a lead-antimony alloy.

Lead-Calcium Cell: A lead-acid cell with plates or grids made from a lead-calcium alloy.

Lead-Selenium Cell: A lead-acid cell with plates or grids made from a lead-antimony alloy to which selenium has been added.

Negative Plate: The lead plate negative electrode immersed in electrolyte from which electrons flow (through the external circuit) to the positive terminal, when the cell discharges. At the negative plate the spongy lead (Pb) active material is converted on discharge to lead sulfate (PbSO₄) with the “production” of electrons. Negative plates are thin, of clean grey or lead color and are always the outside plate.

No-Oxide Grease: Grease used to prevent corrosion and oxidation.

Non-sparking tools: A tool that is non-sparking, non-magnetic, and non-corrosive specifically to be used when working on batteries.

Performance Test: A constant-current capacity test made on a battery after being placed in service, to detect any change in the capacity determined by the acceptance test.

Pilot Cell: Cell in a battery usually selected to become an indicator of the general condition of the entire battery. The pilot cell readings serve as an interim indicator between regularly scheduled voltage and gravity readings of the complete battery.

Positive Plate: The lead plate positive electrode immersed in electrolyte to which electrons flow from the external circuit when the cell is discharging. At the positive plate, the lead dioxide (PbO₂) active material is converted on discharge to lead sulfate (PbSO₄) with the “consumption” of electrons. Positive plates are thicker and of chocolate brown or black color.

Secondary Cell: An electrochemical cell that can be charged and discharged a number of times. Conversely, primary cells are those which cannot be recharged.
Secondary Battery: A set of secondary cells connected together electrically.

Sediment: The active material which separates from the battery plates and falls to the bottom of the jar.

Specific Gravity: The ratio of the weight of a given volume of electrolyte to the weight of an equal volume of water at a specified temperature. This temperature is 77° F (25°C). Pure water has a specific gravity of 1.000.

Station Battery: A stationary battery specifically used at a substation station or power plant to supply emergency dc power to critical electrical equipment. Most of the Station batteries have a nominal voltage of 125 Volt, or 48 Volt and typically consist of 60/24 cells connected in series, with each cell nominally rated 2.08Volts.

Stationary Battery: A secondary battery designed for service in a permanent location.

Thermal Runaway: The event relating to VRLA batteries whereby the negative post of the battery cell exceeds 105°F.

Valve Regulated Lead Acid (VRLA) Cell: Battery cell that is sealed and has a small pressure controlled valve that keeps gases from leaving the cell unless the internal pressures exceed a set value. A major difference with the flooded design is that the VRLA does not have any free-floating electrolyte; the electrolyte is suspended in either an absorbing glass mat (AGM) or a gel substance (GEL), which contributes to its more common name of “gel cell”. It is also referred to as Recombination Cell.

Vented Lead Acid Cell: Also called Flooded Cell or Wet Cell. A cell design which is characterized by an abundance of free electrolysis and evaporation can freely exit the cell through a vent.