Methods for Maintaining and Tracking Connection Integrity on Large Battery Plants

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Abstract

Large stationary battery plants are relied upon to deliver emergency power to mission critical equipment ranging from a few seconds to many hours. The discharge rate and specific load at which they are discharged ultimately determines the actual current demanded of them. Power engineers and system designers strive to make the best material and economic choices to satisfy the needs of the system. From the maintenance perspective, maintaining reliable connection integrity should be considered paramount in operating a reliable battery plant. This paper will explore the fundamentals of establishing, tracking and maintaining connection integrity for large stationary battery plants and discuss the resulting effects of neglecting to address the requirements established by the industry.

Basic Premise

Users of stationary batteries expect a high degree of reliability from their battery plants. A major factor concerning connection integrity focuses on the need for reliable, trouble free connections. Additionally, a minimum amount of voltage drop, hence low power dissipation is desirable during periods of battery discharge. Among several methods, two are popular that have been employed to determine battery connection integrity. Method one involves measuring the voltage drop across each bolted connection during a test discharge. Method two employs the use of an instrument known as a micro-ohmmeter. This paper will deal with the latter of the two measurement methods described and techniques used to track the data taken over time. Simply stated, this is a highly accurate ohmmeter capable of measuring the DC contact resistance with resolution to as low as 1 micro-ohm.

It's Only a Couple of Watts, Right?

To establish a point of reference, consider a 60 cell battery discharging at 1250 amps. Using Ohm's Law, at this rate of discharge, a single connection whose contact resistance is .025 milliohms (25 micro-ohms) dissipates 39 watts. Keeping that in mind, all inter-cell connections are dissipating a total of 2,266 watts. Connector power loss, aside from what must exist as a function of design, is power that cannot be put to use by the critical load. If the connection resistance were to triple to 75 micro-ohms, the total power dissipated through inter-cell connectors then jumps to 6,798 watts! Therefore, it behooves one responsible for battery maintenance to seriously consider this maintenance item with attention paid to detail.

Tooling and Equipment

The equipment and tools necessary to maintain vigilance over connections are few.

- Micro-ohmmeter
- Torque wrench
- Counter-torque wrench
- Wire and/or plastic bristle brushes
- Corrosion inhibitor
- Data recording means

The All Important Benchmark

When a new battery plant is installed, a benchmark or resistance standard must be established in order to track and trend the condition of the connections throughout the life of the battery. The benchmark applies to several types of connections, each with its own unique geometry and resistance profile. The major connection types include inter-cell, tier, rack, aisle measurements.

Terminal plates, devices used to connect multiple cable to a common point present another set of values that require consideration. These include post-to-plate and plate-to-lug connections.

The numbering convention used to locate measurement points uses the cell numbering system of the battery. Usually beginning with the most positive cell in the system and working through the series circuit to battery negative, each connection resistance is measured, usually from post-to-post and recorded with its data categorized based on the type of connection geometry. Once all data has been taken, analysis is required. The maximum allowable resistance value for any given connection type should not exceed the industry or battery manufacturer's recommended maximum for that connection. Due to varying types of connection geometry that exist, several benchmarks must be established.

However, if one party installs and another certifies the battery installation, an additional step is necessary to confirm connection resistance is as low as possible. In such cases, random connections (generally three to five inter-cell, and two to three each of all others) must be selected not only for benchmarking, but detailed visual examinations must be made of those connections to verify they were properly prepared and assembled. Such connections should be selected, disassembled, cleaned, reassembled and tightened to initial torque specification. The method assumes some degree of consistency and expertise was employed by the installer. Clearly, it is not feasible to check <u>all</u> connections by disassembly. <u>That</u> is the purpose of using a micro-ohmmeter. Any connection resistance exceeding the recommended maximum allowable value should be disassembled, cleaned, remade and checked against the benchmark. Re-making the connection generally corrects the anomaly. Figure 1 illustrates data taken for a 60 cell battery plant with a single positive and negative post for each cell.

Tracking and Trending Data

With a benchmark established, keeping track of connection service requirements becomes a function of logging additional data over time which becomes an important part of battery maintenance history. Based on industry recommended practice, a complete set of connection resistance data should be taken once every twelve months. This data is categorized and referenced mathematically to the benchmark. Today's software spreadsheet programs can make the task of data management easier. The use of data logging instruments with RS-232 capability to a PC can further ease number crunching tasks. While this instrumentation reduces time on site, it can be an expensive choice. Alternatively, it can pay for itself over time when large quantities of cell data must be taken and maintained. It is recommended this data be maintained throughout the life of the battery to determine connection rework schedules. Maintenance data is generally required by battery manufacturers when warranty claims are submitted.

What About Corrosion?

Corrosion of interconnections is of concern because over time, the integrity of the connection will degrade. While it is certainly important to acknowledge its existence, it may not be necessary to dismantle and rework a connector by determining its need from visual cues alone. Using a system of strict visual cues to determine rework schedules can result in a tremendous amount of unnecessary labor and down time; two items generally in short supply in today's critical power plants. By using the micro-ohmmeter and recommended practices established by the battery manufacturer and the industry, rework schedules can be managed. The best way maximize rework intervals is to properly install the battery in the first place and keep the battery clean.

When connections are in need of rework, all contact surfaces must be thoroughly cleaned, degreased, neutralized and completely dried before reassembly. Heavily corroded hardware may require replacement, otherwise corrosion will soon return. A general preparation procedure the author has used involves an eight step procedure outlined below.

1. Upon disassembly, clean and degrease all components.
2. Wash all components with a baking soda and water solution
3. Dry thoroughly
4. Terminal posts;
   A) Polish with appropriate media to a clean bright finish appears
5. Connectors;
   A) Polish with appropriate media to a clean, bright finish appears
6. Apply recommended corrosion inhibitor to all parts
7. Reassemble and tighten to initial torque specification
8. Verify connection integrity with a micro-ohmmeter

A Few Words on Safety

Batteries are a unique energy source. They cannot be turned off like an AC system. Even when a battery plant has been removed from the charging source, it remains energized. It is a truly self-contained energy source, capable of very high short circuit current. As a result of their uniqueness, persons who service battery plants should undergo training appropriate to the level at which they will be expected to perform. To the untrained, the battery can pose a serious risk in the workplace. The inherent hazards increase as the cell counts rise. Such is the case with UPS battery plants, where nominal voltages can be as high as 500 to 600 volts. In these situations, a system with minimum of two technicians should be utilized to increase safety levels during maintenance operations.

Basic safety considerations should include, but are not necessarily limited to those items outlined below.

- Safety Equipment (PPE)
  - Safety glasses
  - Insulated gloves
  - Face shield
  - Rubber apron
- Tools
  - Insulated ratchets, sockets, spanners, etc.
  - Lockout / tagout system
- Training
  - Basic electrical safety
  - Product specific
  - Knowledge of the specific system architecture being serviced
    - Number of strings involved
    - Isolation switch gear
    - Alarm architecture
    - Grounding schemes

This paper addresses just one of many aspects of proper maintenance and operation stationary battery plants. With properly trained personnel employing accepted maintenance practices, tools and test equipment, batteries can and do provide many years of service. The author may be contacted for further information. Additionally, please refer to the bibliography listing at the end of this paper for suggested detailed reference material.

Bibliography

IEEE 450-1995 "*IEEE Recommended Practice for Maintenance, Testing, and Replacement of Vented Lead-Acid Batteries for Stationary Applications*"

IEEE 1188-1996 "*IEEE Recommended Practice for Maintenance, Testing, and Replacement of Valve Regulated Lead-Acid (VRLA) Batteries for Stationary Applications*"

IEEE 487-1987 "*IEEE Recommended Practice for Installation Design and Installation of Large Lead Storage Batteries for Generating Stations and Substations*"

Cell No.	Inter-cell	Inter-tier	Inter-rack	Inter-Aisle	Post-to-Plate	Plate-to-Lug	
1	27				7	8	
2	27						
3	28						
4	26						
5	25						
6	24						
7	26						
8	27						
9	23						
10			75		5	8	
11	27				6	7	
12	26						
13	26						
14	26						
15	27						
16	28						
17	43						
18	26						
19	26						
20		125			6	7	
21	27				5	6	
22	27						
23	28						
24	26						
25	25						
26	24						
27	26						
28	27						
29				250	5	7	
30	26				6	8	
31	27						
32	26						
33	26						
34	26						
35	27						
36	28						
37	43						
38	26						
39	26						
40	27	130			7	8	
41	27				6	8	
42	28						
43	26						
44	25						
45	24						
46	26						
47				245	9	8	
48	26				6	7	
49	37						
50	27						
51	26						
52	65						
53	26						
54	27						
55	28						
56	43						
57	26						
58	26						
59	28						
60					6	9	
-	28	128	75	248	6	8	<Avergages
	55	130	75	250	9	8	<Max Measured
	34	153	90	297	7	9	<Max Allowed
	Inter-cell	Inter-tier	Inter-rack	Inter-Aisl	Post-toPlate	Plate-to-Lug	

Figure 1
Example of Initial Connection Resistance Data Collection for a 60 Cell Battery Plant
(All values in micro-ohms)

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Discussion Topics

- Basic Premise
- Power Dissipation
- Tooling
- Benchmarking
- Tracking and Trending Data
- Corrosion
- Safety

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Basic Premise

- Ensure Reliability
- Minimize Voltage Drop
- Maximize Available Power
- Measure of Integrity

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Power Dissipation

- Let's Establish a Reference Point
- Test Case
  - 60 Cell Plant
  - 1250 Amps Discharging
  - 58 Connections @ .025 milliohms
- Dissipation Power = 2,266 Watts

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Power Dissipation

- High Resistance Connections Waste Power!
- Reliability is Reduced
- Connection Failures Can be Catastrophic
  - Serious Damage & Capital Equiment Loss
  - Lost Revenue
  - Equipment Downtime
  - Personnel Safety
  - Customer Dissatisfaction

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Tooling

- Torque Wrench
- Counter Torque Spanner
- Micro-ohmmeter
- Connection Preparation Items
  - Wire Brushes
  - Corrosion Inhibitors
  - Neutralizing Solution

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Benchmarking

- Tracking Connection Integrity Requires a Benchmark
- Differing Connection Geometry
  - Inter-Cell
  - Inter-Rack
  - Inter-Tier
  - Inter-Aisle

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Tracking and Trending Data

- Build a Database Through Normal Maintenance Practices
- Compare Data Annually
- Repair Connections That Exceed Recommended Values

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Corrosion

- Visual Cues Do Not Always Indicate Need for Immediate Attention
- Check Integrity Using Micro-ohmmeter
- Extreme Cases Require Immediate Attention

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Safety

- Batteries Cannot be Turned "Off"
- Service Personnel Must be Trained
  - Basic Electrical Safety
  - Product Technical Training
  - Understanding of System Architecture
  - Know Emergency Procedures

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Safety

- Safety Equipment
  - Rubber Gloves
  - Safety Glasses (Z87.1)
  - Face Shields (Z87.1)
  - Rubber Aprons
- Tools
  - Always Insulated

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Thank You for Attending

Battcon '98

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