

Integrity of Battery Connections: Torque, Grease and Resistance

**Rick Tressler
Senior Training Engineer
Alber
Pompano Beach, FL 33064**

Abstract

Safe and reliable battery operation depends upon a number of things coming together when that emergency power source is needed. Not the least of these is the need for solid continuity of the external bolted connections that provide the path for current to flow from cell to cell and ultimately to the load. All too often, however, the importance of these connections is misunderstood. Frequently, they are improperly maintained or ignored altogether. While such maintenance appears to be elementary to trained personnel, it is frequently carried out by incorrectly or completely untrained personnel. Manufacturer installation instructions are frequently disregarded. The results can be catastrophic failure of what is truly, the most important subsystem in an emergency power application. This paper will discuss the hardware, proper installation, errors associated with installation, maintenance and testing of these connections. Initial and periodic connection torque requirements and use of corrosion inhibitors will also be addressed. It is vitally important that the manufacturer's installation, operation and maintenance manual specific to the battery be thoroughly read and understood before work begins. Questions should be directed to the manufacturer directly or the designated authorized sales or service organization.

Introduction

Stationary battery system interconnections discussed in this paper refer to those which are field-installed by the end user or contractor. They are generally referred to as intercell, interunit, intertier, interrack, interstep, intershelf and interaisle connectors. Types of connection methods are very similar across many manufacturers. Connectors are frequently lead, tin, or nickel plated copper bus bars. They are fabricated as needed to meet the specific battery and its application. Connectors also take the form of wire or heavy cable and are usually terminated with compression lugs.

Regardless of their physical construction, the number and thickness of the connectors is a function only of the electrical requirements, battery construction, type and application. Connectors are sized not for their current carrying capacity; rather, they are sized to afford the desired minimum voltage drop between cells. Excessive voltage drop translates to energy lost in the form of heat; it is wasted energy. When rigid connectors are utilized for low rate, long duration applications, a single, 1" (25mm) tall, 1/16" to 1/8" (1.5 – 3mm) connector may be sufficient. Conversely, short duration, high rate applications generally employ parallel connectors approaching 2" (50mm) in height and 1/2" (12.5mm) in thickness. In very high rate applications, additional "auxiliary" intercell connectors are stacked on top of the primary connectors to ensure lowest possible voltage drop and current handling capability during discharge. Small applications, such as a 50 amp hour substation battery are frequently interconnected with AWG #6 wiring. Where used, interaisle cables are usually the longest of the battery interconnections and are not normally supplied with the battery system. In those situations, it is up to the system designer and installer to properly size these conductors.

As can be seen, size and quantity of connectors is wide ranging and is an important consideration. In the end, the battery manufacturer sizes the connectors for the end user based on application information provided.

All battery connections are equally important. Proper preparation of connectors, battery terminals, application of corrosion inhibitors and proper torque are essential. When performed properly and maintained in accordance with manufacturer instructions, connections can and do survive for much if not most of the installation life of the system without need for corrective action. The notion that connections need to be disassembled, cleaned and reworked routinely or on a frequent basis is a misnomer.

It is worth noting that the different battery types use connectors better suited for that particular type. This is not a hard and fast rule, however. For example, large format vented lead-acid (VLA) as well as their valve regulated lead-acid (VRLA) counterparts while generally employing lead or tin plated copper intercell connectors, may also use flexible cables to accomplish the connection requirements. Smaller VLA and VRLA types such as multicell units generally employ a flexible cable terminated with compression lugs but traditional intercell connectors are also employed.

Initial Installation

Lead Plated Copper Connectors

The intent of proper connection preparation is to establish a clean, secure connection with the lowest possible dc resistance, given the connection hardware supplied with the battery. Some interconnecting hardware requires more preparation than others. Such is the case for lead plated connection hardware.

Lead plated copper connectors have been in use for many years. The practice continues today. The lead plating oxidizes when exposed to air, so they appear to have a dull gray finish. See Figure 1. Proper cleaning and application of an approved corrosion inhibitor prior to assembly is essential. Of note is the fact that the connectors on the battery installation in Figure 1 were not properly cleaned or greased prior to assembly. There will be more on this topic later. Using lead plating over the copper (an electroplating process) is intended to protect the base metal from what would certainly be corrosive effects due to the proximity to gases evolving from VLA cells, spilled water and/or electrolyte. When a number of interconnecting cable groups exceed that which can be accommodated by the battery terminals, a terminal plate is used. The makeup is the same as the intercell connector; lead plated copper in this case.

Preparation of these connectors generally involves removal of the surface oxidation layer and is covered in the installation instructions; a copy of which should be on hand during the process. While there is no universal material or tool for this purpose, the use of a plastic bristle brush (occasionally supplied in accessory kits) abrasive pad or even burlap is used. Scotch Brite® has been used with considerable success for many years. It has been the author's direct experience that battery manufacturers do not seem to have a problem regarding its use. With that in mind, the use of wire brushes should be avoided as use of such tools will readily remove significant amounts of the thin layer of lead plating; the thickness of which is approximately 0.004" (0.1mm). Powered hand tools, i.e., drills, buffer wheels and other machinery turning polishing flap brushes and other abrasives are absolutely not recommended as this activity launches lead dust into the work area, creating a health safety issue. This can result in complete removal of the lead plating resulting in exposed copper.



Figure 1. Single lead plated copper intercell connector

Tin Plated Copper Connectors

Tin plated connectors have become more popular in recent years and for some manufacturers, have become standard for their large VLA and VRLA products. Lead plated connectors can be obtained upon request. More users are now choosing tin. See Figure 2. Their appearance is characterized by a bright, clean, smooth and shiny surface. In recent years, Restriction of Hazardous Substances Directive (RoHS) compliance has become an issue with battery users particularly in the UPS/data center market. RoHS was started in the European Union (EU) and its effect has been seen in the U.S. Battery manufacturers have added the tin plated connector option to meet the RoHS requirements by some end users outside the EU. Batteries of course are still allowed to contain lead; anything that is not permanently attached to them is not. The cost is close to the same in that the tin plating is much thinner. Corrosion testing has been conducted, and while lead is still superior, tin also performs well. The environment in a battery room these days is significantly better than when lead plated connectors were first used.

Generally, wiping the connector free of dust and other potential contaminants with a dry soft cloth is sufficient. Lead oxide is an insulator, and can add significant resistance in the contact area if cleaning prior to installation is not performed. Tin does not easily oxidize. The oxidation that *does* form on tin is still a relatively good conductor, which is why it is used as a plating metal for many electrical connection devices. Therefore, it does not need the rigorous cleaning as does lead. It should be noted that an installer used an abrasive cleaning pad on tin plated intercell connectors on a site with many hundreds of cells, resulting in fine but very noticeable scratches. Reportedly, the end user demanded all be replaced. Installers – read the installation instructions to avoid losing your profit margin!

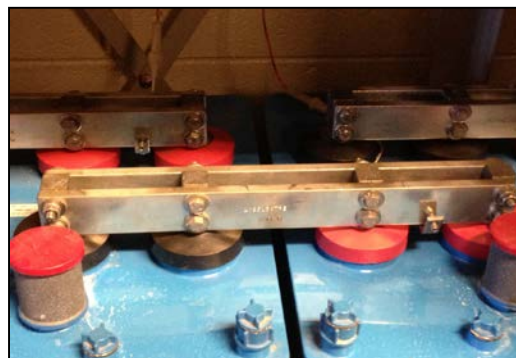


Figure 2. Parallel tin plated copper intercell connectors

Nickel Plated Copper Connectors

Nickel plated connectors are used primarily on Nickel Cadmium (NiCd) battery systems. Tin plated connectors present a galvanic corrosion issue with the cell's nickel terminals.

Flexible Cable Connectors

In addition to intercell and interunit connections, a manufactured flexible cable is generally used when there is a connection transition between racks, tiers, steps, rows or aisles. Some manufacturers use them as the default connection method. Their use in cabinet-style VRLA battery systems is common.

Typical construction consists of a length of copper cable terminated at each end with a one or two-hole compression lug as required by the battery model and application. Some users specify tinned copper stranded cables to aid in fending off corrosion effects on VLA batteries. Adhesive/sealer-lined heat shrink tubing is frequently applied to cover the lug-to-barrel interface to protect it from acid contamination. In contrast, a lug with an inspection hole adjacent to the tongue of the lug is generally a requirement in many telecommunications power system installations. It should not be covered. Depending on the battery manufacturer, specific instructions may be included in the installation manual regarding preparation of the lugs prior to assembly. Some manufacturers provide the cables with lead plated lugs.

Welded Lead Alloy Connectors

These intercell connectors are factory installed and require no attention during installation. Periodic inspection during their service life is recommended.

Uses in Addition to the Obvious

Intercell connectors are used by some battery monitoring equipment manufacturers as a shunt for measuring discharge and ripple current. The connector can be drilled with appropriately spaced holes in it to provide a calibrated resistance. Sense leads are connected to report the shunt voltage drop back to the monitor. It is important that the sense leads are periodically checked for security and corrosion, otherwise the accuracy of the reported reading will suffer.

Cell/Unit Terminals

During installation, preparation of cell/unit terminals is just as important as the connector. Attention to cleaning is frequently ignored. Terminals frequently ship from the factory with corrosion inhibiting grease applied to minimize the effects of corrosion during transit and storage. The grease needs to be removed and the terminal cleaned prior to installation of connectors. Factory application of grease does not negate the need to clean. Remember, the goal here is to establish a clean, protected, secure, low resistance connection. Terminal construction for lead-acid batteries can be generally categorized into two types; those which are a solid lead alloy and those utilizing a lead alloy terminal with a copper insert. Copper inserts are commonly used in batteries designed for high rate discharges. Such terminal design reduces connection resistance. Popular types for lead-acid batteries include square post, recessed threaded insert, chair and flag to name a few. NiCd batteries generally utilize a nickel plated recessed threaded terminal to receive a bolt or a threaded post which requires a nut to secure the intercell connector or cable.

Cleaning cell terminals is conducted in a similar manner and with the same attention to the battery manufacturer's instructions. Most require cleaning prior to assembly. It cannot be over-emphasized that the installation manual must be followed. In the author's opinion, damaging a battery and voiding the warranty occurs too often simply because the installer did not read the manual.

Here, as with connectors, the type of terminal determines the cleaning method. Copper-inserted terminals and posts are usually cleaned with an abrasive pad or plastic bristle brush as previously described. Wire brushes are not to be used. Removal of the thin lead plating can occur, leaving the copper underneath exposed to corrosion. When multiple personnel are involved, consistent cleaning methods and techniques will assure consistent battery-wide connection resistance readings.

Assembly Hardware

In a large number of applications, assembly hardware takes the form of stainless steel. It is frequently type 18-8 or 316 with the latter of the two having higher nickel content. This results in a higher resistance to corrosion. Type 316 is generally the metal of choice for batteries employed in high rate applications. This particular hardware identified with the numbers "316" stamped on bolts, washers and lock washers. Otherwise, if stainless, it will be 18-8 or other stainless.

Lead encapsulated brass nuts are also used in combination with a threaded brass stud. These are generally found on VLA batteries used in telecommunications and small switchgear batteries where lead alloy posts and lead plated connectors are used.

Galvanized steel hardware should be avoided as it is subject to corrosion and causes galvanic corrosion when used with lead and copper.

Regardless of metallurgy, nut/bolt hardware is not intended to be greased prior to assembly unless the installation instructions specifically indicate. Torque specifications are based on un-lubricated threads.

Corrosion Inhibitors

From the title of this section, one might surmise that some level of corrosion, hence connection degradation may become a maintenance issue. Not all battery manufacturers prescribe the use of corrosion inhibitors. The installer should consult the installation manual. As to just how much of a maintenance issue, the battery person's universal response to that is "it depends" and it is absolutely the truth. The basic premise of using a corrosion inhibitor is to provide an oxygen seal around the connection the installers spent hours cleaning and assembling. Preventing electrolyte attack is the goal. Use of these compounds, along with proper surface preparation aids in maximizing the time connections remain within specification before they must be disassembled and reworked.

One of two types of corrosion inhibitors are applied to connections used on lead-acid batteries. Keep in mind that a specific battery manufacturer may not require its use. Corrosion inhibitors include *No-Ox-Id Type A* grease (aka No-Ox) and *NCP-2* from NoCo. The author's use of the brand names is not a product endorsement. Both have been on the market for many years with No-Ox being in use the longest. Usually, one of these will be provided in the battery system accessory kit.

There are numerous ways to apply these products. No-Ox grease can be applied directly from the container to the battery terminals and connectors. A thin, uniform film is all that is necessary. Coating the entire length of an intercell connector is not recommended. Installers will run out in short order. The extra grease application is unnecessary and serves no useful purpose. Application should be limited to the portion of the connector that actually contacts the battery terminal. Another method recommended by some manufacturers is to heat the grease to approximately 160°F (71°C). This results in a somewhat thick consistency. Connector ends are dipped into the hot grease, providing a uniform, but fairly thick coating. With cell/unit terminals properly cleaned and ready for assembly, the connector(s) are attached using the supplied nut and/or bolt and washer hardware. Note that No-Ox grease has a minimum flash point of approximately 450° F (232° C). Extreme caution should be exercised to avoid a fire when heating the grease.

NCP-2 is not to be heated. It is applied directly from the container with a small brush frequently part of the container cap. It is brushed lightly on the ends of the connectors where contact is made with the cell/unit terminal.

NiCd battery manufacturers do not generally include requirements using the aforementioned products. Neutral Vaseline has been supplied by some, while others specify none, requiring the hardware only to be clean and free of any potential contaminants that would prevent a good connection.

Installation of Connection Hardware

One might consider this part of the installation to be a “no-brainer”. For trained battery technicians, that’s true. Nut/bolt assembly hardware usually includes the use of flat-cut washers made of stainless steel. Lock washers are supplied at the discretion of the battery manufacturer. There is a rounded edge and a sharp edge on the flat washer. The sharp edge is the result of the stamping process. The rounded edge of the washer should be placed against the intercell connector or cable lug. This keeps the sharp edge from cutting through the plating, exposing the base metal, usually copper, to potential electrolyte attack and corrosion.

When nuts and bolts are used, positioning of hardware should be such to facilitate access to the nut with a torque wrench. Hardware should be assembled manually, finger tight. Use of power tools to spin down the assemblies should be avoided.

Connection Torque and Tightening the Hardware

Battery installation and maintenance cannot be safely performed without properly insulated tools. When a second wrench is required to hold the bolt head, it too must be properly insulated. Associated sockets are also generally insulated. The use of electrical tape to insulate any tool that is going to be used on energized equipment such as batteries is not acceptable. Do so at your own risk.

Every battery product this author has worked on provides at *least* an initial torque specification, with many usually including maintenance or “maintenance torque” specification for subsequent tightness checks on a continuing basis. The common unit of measure for torque for battery work is the inch-pound (lbf.in) or Newton-meter (Nm). Many torque wrenches include a graduated scale for one or both units of measure depending on the tool. A 3/8” (9.5mm) square drive, click-type wrench is typical. **Do not confuse Newton-meters with inch-pounds.** See Table 1 for a lbf.in to Nm conversion table. Do not confuse foot-pounds with inch-pounds.

Table 1. lbf.in to Nm Conversion			
lbf.in	Nm	lbf.in	Nm
10	1.3	100	11.3
20	2.2	110	12.4
30	3.4	120	13.5
40	4.5	130	14.7
50	5.6	140	15.8
60	6.8	150	16.9
70	7.9	160	18.1
80	9.0	170	19.2
90	10.2	180	20.3

When tightening bolted connections, the nut on a nut/bolt hardware assembly is turned with the torque wrench. An open or box end wrench is used to prevent the bolt from rotating. Tightening continues until the technician feels a “click” in the handle, indicating the hardware has been tightened to the selected value. Do not continue tightening the hardware past this point. Be aware that a battery manufacturer or end user’s engineering installation technical specification may require a follow up torque check within a certain period of time to verify all bolted connections are in compliance. Such checks are common in the nuclear user industry.

Verifying Integrity of New Connections

After connections have been tightened, their resistance should be measured and recorded. Baseline data will be used for maintenance personnel going forward. Consistent use of the instrument, i.e., test lead or probe placement is very important. Placement on nut/bolt hardware is to be avoided. It is noteworthy that not all batteries are built such that a measurement can be accomplished. Limitations exist as a result of battery and connector design. It has been the author’s experience that manufacturers frequently require periodic connection tightness checks to ensure a good connection. Measurement of connection resistance requires use of a micro-ohmmeter or other suitable low resistance measurement instrument. Some of the internal ohmic test equipment available today may include connection resistance measurement functionality. Connection resistance values are to be recorded and maintained in a permanent record to meet battery manufacturer warranty requirements. Measurements for different connection geometries are segregated, i.e., intercell, interrack, etc. An average value for each type of connection is then determined.

Generally, investigation into any connection where resistance exceeds 10% of the average or 5 micro-ohms (whichever is greater) for a given connection type is needed. First, re-torque the connection to verify it is tight. If this does not lower the resistance, the connection must be disassembled, cleaned, reassembled and tested again.

Common installation errors resulting in unacceptably high resistance include, but are not limited to the items listed below.

- Failure to properly clean connectors and/or terminals prior to assembly
- Failure to properly tighten the connection hardware
- Use of different connectors for the same type of connection
- Erroneous placement of a washer between a connector and the battery terminal

For details regarding recommended measurement technique, allowable deviation from average, corrective actions, etc., consult the applicable Institute of Electrical and Electronics Engineers (IEEE) standard, recommended practice or guide(s) for the particular battery being tested. Refer to Table 2.

Table 2. IEEE Documents Addressing Connection Resistance	
Battery Type	Applicable IEEE Document
VLA Battery Installation	IEEE 484-2002
VLA Battery Maintenance and Testing	IEEE 450-2010
VRLA Battery Maintenance and Testing	IEEE 1188-2005
VRLA Battery Installation	IEEE 1187-2013
Nickel Cadmium Battery Installation Maintenance and Testing	IEEE 1106-2005

Periodic Maintenance of Battery Connections

The need for periodic visual inspection and measurement of connection resistance is important. Generally, measurements are performed annually or when an abnormal battery condition occurs, such as a deep discharge. Stationary batteries are rarely discharged. Maximum reliability is the intended goal.

When connection resistance rises to an unacceptable value, the cause should be investigated. The recommended course of action, per the applicable IEEE document in Table 1 specifies two such courses. First, apply the battery manufacturer's recommended maintenance torque value, if applicable. This will be located in the operation and maintenance manual for the selected battery. If this action does not result in a lower resistance, disassembly, cleaning and reassembly is required, followed by verification the corrective action was successful.

Corrosion is one of the causes for an increase in connection resistance. However, visual evidence of corrosion is not always indicative of high resistance. A measurement must be made to confirm this. If resistance is acceptable, in the interest of time management, maintenance activities can be deferred to a later date.

Corrosion can become extensive to the point that cleaning connectors has marginally positive results. In such cases, complete replacement of the connectors and nut/bolt hardware as well as terminal/post resurfacing may be required.

Summary

This paper, with just these few topics covered, should serve as an indicator that there is much more to installing and maintaining stationary battery systems than many seem to think. Trained personnel are essential to the reliability of the system not only from an installation perspective, but for continued safe and proper operation. Anytime a stationary battery is involved in a power system, it's there because the user cannot tolerate an interruption in that power system. Making it as reliable as possible should be job one.