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Interface Practices Subcommittee

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SCTE 275 2021

Electrical Grounding and Bonding for Cable Broadband Network Critical Facilities

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1. Introduction

1.1. Executive Summary

This standard provides a description of basic practices to obtain a reliable, low impedance grounding and bonding system in communication networks.

There are five principal objectives for providing a dependable low impedance grounding and bonding system. These include:

1. Personal Safety: Minimize the development of electrical potential that could create a shock hazard to personnel, within and between metallic frames and structures.
2. Equipment Protection: Provide adequate fault current paths so any installed overcurrent devices can disconnect faulted circuits to reduce the possibility of fire and limit damage to the critical equipment.
3. Equipment Operation: Provide an equalized ground reference to electronic communication circuits connected to the ground plane.
4. Electrical Noise Reduction: Assist in the reduction of electrical interference by maintaining low impedance paths between ground points throughout the communication system.
5. Reliability: Provide a grounding system that resists deterioration and requires minimal maintenance.

1.2. Scope

This document includes practices for exterior system grounding and bonding, interior grounding systems, surge protection, roof mounted lightning protection, environmental handling for electric static discharge (ESD) sensitive equipment, commissioning, and maintenance.

1.3. Benefits

Broadband networks can become more dependable when appropriate standardized grounding and bonding procedures are followed. The recommendations herein also ensure operational safety.

1.4. Intended Audience

Cable operators, contractors, and cable industry equipment manufacturers should familiarize themselves with this publication.

1.5. Areas for Further Investigation or to be Added in Future Versions

Possible topics that could be added include shielding and ground fault detection.

2. Normative References

The following documents contain provisions, which, through reference in this text, constitute provisions of this document. At the time of Subcommittee approval, the editions indicated were valid. All documents are subject to revision; and while parties to any agreement based on this document are encouraged to investigate the possibility of applying the most recent editions of the documents listed below, they are reminded that newer editions of those documents might not be compatible with the referenced version.

2.1. SCTE References

[SCTE 226] ANSI/SCTE 226 2015, Cable Facility Classification Definitions and Requirements, https://scte-cms-resource-storage.s3.amazonaws.com/Standards/ANSI_SCTE%20226%202015.pdf

2.2. Standards from Other Organizations

[IEEE 3003.1] IEEE STANDARD 3003.1 — IEEE Recommended Practice for System Grounding of Industrial and Commercial Power, https://standards.ieee.org/standard/3003_12019.html

[IEEE 3003.2] IEEE STANDARD 3003.2 — IEEE Recommended Practice for Equipment Grounding and Bonding in Industrial and Commercial Power Systems, https://standards.ieee.org/standard/3003_2-2014.html

[IEEE 81] IEEE 81-2012 - IEEE Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Grounding System, https://standards.ieee.org/standard/81-2012.html

[Ericsson] Ericsson GR-295 Mesh and Isolated Bonding Networks: Definition and Application to Telephone Central Offices, 2004

[NFPA 780] NFPA 780 2020, Standard for the Installation of Lightning Protection Systems

[ATIS] ATIS 0600313: Telecommunications – Electrical Protection for Telecommunications Central offices and Similar Type Facilities, 2013

[CSA] CSA b72 Installation Code for Lightning Protection Systems, 2020

[NFPA 70] NFPA 70 National Electrical Code, 2020

[CSA C222.1] CSA C22.1 2021 – Canadian Electrical Code. Part I, Safety Standard for Electrical Installations

[ANSI TL] ANSI TI.313-2003 Electrical Protection for Telecommunications Central Offices and Similar Type Facilities

3. Informative References

The following documents might provide valuable information to the reader but are not required when complying with this document.

3.1. SCTE References

No informative references are applicable.

3.2. Standards from Other Organizations

No informative references are applicable.

3.3. Published Materials

No informative references are applicable.

4. Compliance Notation

shall	This word or the adjective "***required***" means that the item is an absolute requirement of this document.
shall not	This phrase means that the item is an absolute prohibition of this document.
forbidden	This word means the value specified shall never be used.
should	This word or the adjective "*recommended*" means that there may exist valid reasons in particular circumstances to ignore this item, but the full implications should be understood and the case carefully weighted before choosing a different course.
should not	This phrase means that there may exist valid reasons in particular circumstances when the listed behavior is acceptable or even useful, but the full implications should be understood and the case carefully weighed before implementing any behavior described with this label.
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deprecated	Use is permissible for legacy purposes only. Deprecated features may be removed from future versions of this document. Implementations should avoid use of deprecated features.

5. Abbreviations and Definitions

5.1. Abbreviations

AC	alternating current
AHJ	authority having jurisdiction
ANSI	American National Standards Institute
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
ATS	automatic transfer switch
AWG	American wire gauge
BDCBB	battery distribution circuit break bay
BDFB	battery distribution fuse bay
BN	building network
BRSB	battery room safety bar
CBN	common building network
CCEGB	coax cable entrance ground bar
CEGB	cable entrance ground bar
CF	critical facilities
CRGB	computer room ground bar
CSA	CSA Group (formerly the Canadian Standards Association)
DC	direct current
DCGB	DC positive bus ground bar

ENT	electrical non-metallic tubing
ESD	electrostatic discharge
FCEGB	fiber cable entrance ground bar
FEC	fiber entry cabinet
FGB	frame ground bar
HEGB	headend equipment ground bar
IEEE	Institute of Electrical and Electronics Engineers
IGZ	isolated ground zone
kcmil	thousand circular mils
MCM	thousand circular mils, see kcmil
MGB	master ground bar
MSS	main AC service switchboard
NEC	National Electrical Code
NFPA	National Fire Protection Association
OSP	outside plant
PANI	producer absorber non-isolated isolated
PM	preventative maintenance
PVC	polyvinyl chloride
RH	relative humidity
SCTE	Society of Cable Telecommunications Engineers
SGB	secondary ground bar
SPD	surge protective device
SSGB	sub-system ground bar
TCEGB	telco cable entrance ground bar
THHN	thermoplastic high heat-resistant nylon-coated
TVSS	transient voltage surge suppressor
UPS	uninterruptible power supply

5.2. Definitions

American wire gauge	A US standard specifying diameter of a round wire usually made of copper and aluminum. The larger the AWG number, the smaller the diameter (gauge).
air terminals	Devices that are located at specific building sections, primarily the roof, that are likely to be struck by lightning. Their purpose is to intercept a lightning strike.
aisle feeder	An aisle feeder is an equipment grounding conductor that connects a secondary ground bar (SGB) to an equipment frame ground bar (FGB); typically, 2/0 AWG or larger in size, it connects to an equipment FGB via a ‘tapped’ #6 AWG.
cabinet/rack frame ground conductor	A #6 AWG conductor that runs from the row aisle feeder ground conductor to the cabinet/rack.
cable entrance ground bar	The ground bar where telecommunication cables that enter the building are terminated.
counterpoise ground	Electrical grounding of a system that is a closed loop shape (triangle, square, etc.) versus a radial system (spokes of a wheel without the ends being connected)
down (or main) conductors	Stranded copper lightning protection conductors that provide a path for lightning currents down the exterior sides of a building.

exothermic welding	A weld that is used for electrical connections that minimizes introduction of resistance due to the weld.
ground	The earth.
grounded (grounding)	Connected (connecting) to ground or to a conductive body that extends the ground connection.
grounded conductor	A system or circuit conductor that is intentionally grounded.
grounding conductor equipment	The conductive path(s) that provides a ground-fault current path and connects normally non–current-carrying metal parts of equipment together and to the system grounded conductor or to the grounding electrode conductor, or both.
grounding electrode	A conducting object through which a direct connection to earth is established.
grounding electrode conductor	A conductor used to connect the system grounded conductor or the equipment to a grounding electrode or to a point on the grounding electrode system.
halo ground ring	A type of ring ground that, instead of being installed outside and underground, is installed inside, near the top of a building or structure. The ground reference for all equipment inside the area being protected is separate from the halo. The halo is connected to the main building ground, Electrical equipment is also often placed in fully enclosed metal cabinets, which function as Faraday cages to further protect the equipment. A typical halo ground is constructed of #2 insulated copper wire and is installed six inches below the ceiling, and entirely encircles the area that it is protecting.
isolated ground zone	The isolated ground zone or IGZ is a dedicated zone or area inside a facility that contains any equipment that needs to have an isolated ground. All equipment located within this IGZ **shall** be electrically isolated from all external grounds except for those equalized through a connection to other specifically isolated ground bars.
main aisle feeder ground conductor	Runs from the SGB, (a 2/0 AWG or 4/0 AWG conductor) perpendicular to the rows of cabinets/racks, usually taps down to a 2/0 AWG row aisle feeder conductor.
PANI	P - surge producers (typically, conductors coming from cable entrance ground bars, as well as generators, UPSs, and transformer enclosures) A - surge absorbers (typically contains connections to building steel, the exterior ground ring, the cold-water pipe, if metallic, and the incoming main AC service ground bar – the multi-ground neutral bond) N - non-isolated ground zone equipment grounds (typically includes secondary ground bars for equipment ‘aisle feeder ground conductor’ cabinet/rack grounds, ladder rack, etc.) I - isolated ground zone equipment grounds (typically equipment associated with the legacy electronic telephone switch, some logic grounds and the DC plant reference ground)
secondary ground bar	Any ground bar that is downstream of the master ground bar that collects aisle feeder and other grounds. This is not a cable entrance ground bar. Also known as foreign object ground (FOG) or auxiliary ground bar (AGB).

row aisle feeder ground conductor	Runs from the main aisle feeder ground conductor, parallel to the rows of cabinets/racks, usually a #2 to 2/0 AWG conductor that taps down to a #6 AWG cabinet/rack frame ground conductor.
single point ground system	The single point ground system refers to the design of a grounding system where all internal SGBs, grounding electrode conductors and other necessary local ground conductors are all terminated to the master ground bar (MGB), which becomes the 'single point' of the single point ground system.
uninterruptible power supply	An AC power supply used to provide reliable, conditioned AC power to electronic equipment and systems that typically operate 24 hours per day and that cannot tolerate a momentary power outage. An uninterruptible power supply maintains AC power, typically from storage batteries, in the event of an outage in the AC mains.

6. Intended Application

The recommendations presented herein are intended for cable and similar telecommunication operators. The reader of this document is reminded to comply with all applicable regulatory and safety requirements. These include but are not limited to requirements related to basic personnel safety and fire prevention and national (electric) codes when these requirements exceed those described in this document. Any authority having jurisdiction (AHJ) might have additional requirements.

7. Exterior Grounding and Bonding System

This section of the document describes exterior grounding and bonding systems.

7.1. Definition

The exterior grounding system establishes a direct path of known low impedance for all power, communication, and signal systems. The exterior grounding system also provides a path to earth for the discharge of lightning strikes, restricts step and touch potential gradient in the area accessible to persons, and assists in the control of electrical noise in signal and control circuits by minimizing voltage differentials. Currents associated with power faults and noise typically use this path to return to their source, whereas currents associated with lightning use this path to equalize the charge established on the earth's surface during storms.

7.2. Design Considerations

Service providers target a range of earth resistance values, varying from 5 ohms to 25 ohms, depending on company policy, applications, and specific conditions. In general, the lower the resistance, the better, but 25 ohms *should* be considered a maximum.

7.3. Soil

The composition of local soil will affect grounding. Test soil resistivity to achieve a targeted ground system resistance value. Use enhanced grounding methods (counterpoise, chemical/electrolytic rods, backfill materials) if necessary. The following issues *should* be considered:

1. Determine the specific conductive properties of the local soil by measurement of the soil resistivity at the existing (for expansions) or proposed site location.
2. Review soil boring measurement reports to determine soil classifications and water content at various depths and determine the seasonal variations in the water table.

3. Review exposure to transferred ground potentials by electric power companies during phase to ground faults on their distribution system.
4. Some soils, (sandy) have a high resistivity so that conventional ground rods or ground electrode systems might not be able to obtain the desired ground resistance.
5. Enhanced ground electrodes or ground enhancement materials (list general methods/materials) *may* be required to meet grounding specifications.

7.4. Resistivity

Best practices for measuring soil resistivity are described in the latest IEEE Std 142, IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems (Green Book) and IEEE Standard 81, Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System.

7.5. Tower Grounding

All earth stations and tower systems including legs, and posts ***shall*** be grounded to a tower ground ring with a minimum of #2 copper with exothermic welds. The tower ground ring ***shall*** be bonded to the facility ground ring. On decommissioning of tower and earth stations, all transmission cables ***shall*** be disconnected from the headend ground system.

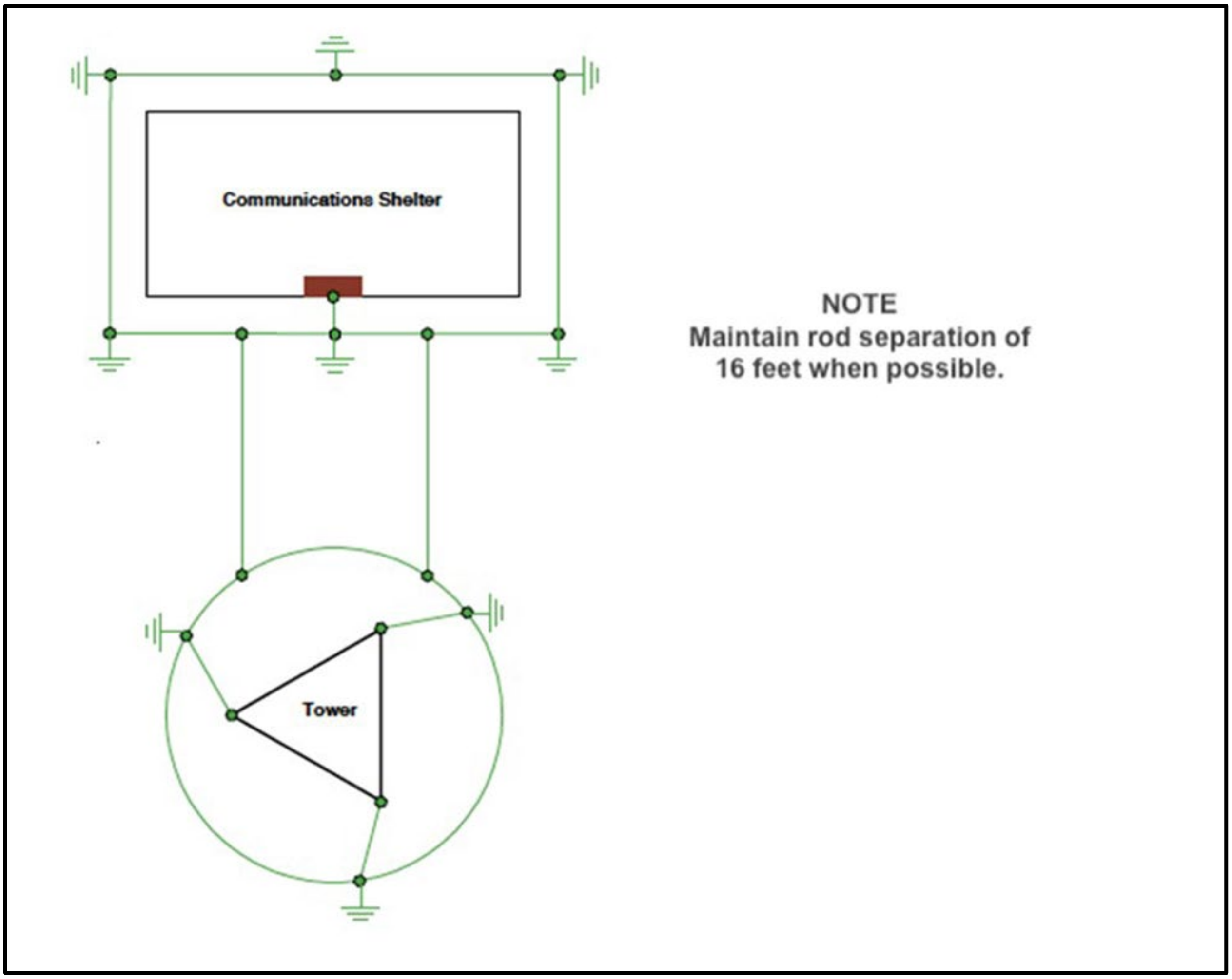

Figure 1 - Typical Tower Ground Ring Bonded to Facility Ground Ring

7.6. Ground Rings

As a minimum, the exterior ground ring installed around the facility *should* consist of a minimum #2 copper conductor buried at a depth of 30 inches below grade or below the local frost line, whichever is greater. At intervals of 20 feet, copper clad ground rods, ¾ inch x 10 feet long, *should* be connected to this ring along its entire length. These ground rods *should* be exothermically connected to the ground ring and driven vertically into the earth with the top of the rods driven to a depth equal to the depth of the ground ring conductor. If determined through design calculations that this minimum system will not produce a system having a resistance to remote earth of a maximum of 25 ohms with every reasonable effort to achieve 5 ohms or less, then additional grounding provisions *should* be incorporated into the design and depicted on the construction drawings.

Ground rod inspection sleeves, test wells or hand holes *should* be installed at critical locations along the ground ring. These locations will differ depending on the type of facility being built, but as a minimum, *should* include connection points between the ground ring and the master ground bar (MGB) and connection points between the ground ring and the tower ground ring, where applicable. In addition to the connections described in the preceding sections, the building exterior ground ring *should* have connections to the master ground bar (2, at opposite locations along the facility ground ring with both conductors being the same length), interior halo ground ring (at each corner), the frame of each generator enclosure and the main AC service entrance switchboard's ground bar. In addition, if the facility has a roof mounted lightning protection system, the facility ground ring *should* be connected to each lightning protection down lead. Each of these connections *should* take place at a ground rod that is exothermically connected to the ground ring conductor and the conductor of interest.

Any security fence installed around the facility or tower ***shall*** be connected to the closest available ground ring, or if not readily accessible, to a driven ground rod. A minimum of one grounding connection per 50 feet of fence *should* be installed. In addition to these connections to the fence, all manual gate posts ***shall*** be bonded across each rotating post. Connections to the fence *should* be exothermic and occur at a ground rod installed at two feet from a fence post. This same ground rod *should* be connected to the ground ring. Conductors *should* be bare #2 AWG copper buried to a depth of 30 inches or below the frost line, whichever is greater. Similarly, ground rods ***shall*** be 5/8-inch x 10 feet long, copper clad steel buried to a top of rod depth of 30 inches or below the frost line, whichever is greater. In addition, all exterior metallic structures, drains, mechanical/electrical equipment and storage tanks ***shall*** be connected to the closest available ground ring. Finally, all outdoor lighting support structures *should* be grounded to either the buried ground ring or a separate ground rod if the ground ring is not readily accessible.

8. Interior Grounding and Bonding System

8.1. Definition

The interior grounding system consists of an interconnected system of grounding conductors, ground bars and connections. This system connects to all incoming grounding systems, all interior equipment ground bars, interior surge generating equipment, miscellaneous metallic systems and the exterior buried grounding system. The interior grounding system is installed for equalizing ground potentials between interfacing equipment and to provide a direct path for fault currents to flow as they attempt to return to their source. If this path has a low resistance, then a protective device will sense the fault current and isolate the faulted circuit. Equipment and equipment racks installed in communications facilities are subjected to varying ground potentials due to their connections (intentional or unintentional) to exterior grounding systems such as incoming power system neutral and ground, telephone cable shields, fiber cable shields, cold water pipes, etc. In addition, there are internal surge generators that can cause voltages (potential) to occur on the exterior grounding systems. Ground is used by the electronic equipment (and power equipment) for signal reference purposes. For example, ground is used as a voltage reference when data is exchanged between two pieces of communication equipment over copper wires, coax or copper based twisted pair. These communication cables attach to the ground planes inside the equipment and, if there is a voltage difference between the equipment, a current will flow to equalize the voltage difference. This current, especially during times of large voltage differences (i.e. lightning, ground fault), can be very high, often leading to equipment failure.

As mentioned earlier, the objectives for providing a dependable low impedance grounding and bonding system include:

1. Personal safety
2. Equipment protection
3. Equipment operation
4. Noise reduction
5. Reliability

In addition to the above, the grounding system creates a low impedance path to ground for transient over voltage, lightning strikes and particularly electrical noise, which would otherwise harm electronic equipment.

Ericsson standard GR-295 *may* be used as a reference for grounding telecom buildings.

8.2. Design

The concept of single point grounding for cable facilities class A through D as defined in Figure 2 *should* be adhered to in the design and installation of interior grounding systems specified herein.

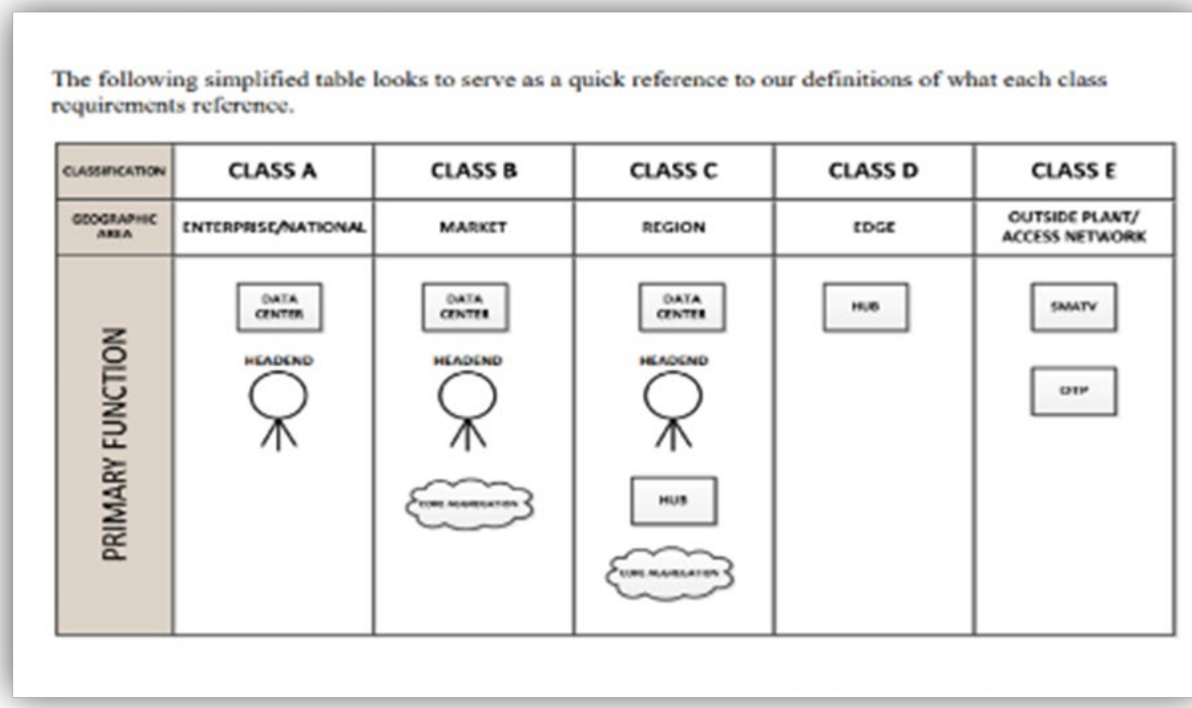

Figure 2 - Facilities Classification[1]

A properly designed interior grounding system will equalize the various grounding system potential differences, and thereby, minimize the current flowing through the equipment communication cables. It will also enable protective devices to detect fault currents and quickly isolate faulted circuits.

There is a need to control fast rise time electrical surges, which produce high potential differences between the ends of copper wires and ground bars. A fast rise-time current surge (i.e. lightning) produces this potential difference across its length as current literally travels down the conductor. The actual voltage developed across the conductor is largely determined by the inductance of the conductor times the rate of rise of the traveling current surge. For example, if the inductance of the conductor is equal to 0.99 microhenrys and the rate of rise of the current surge is equal to 100,000 amperes per microsecond, then the voltage developed across the conductor is equal to 99,000 Volts. In live voltage measurements, more than 10,000 Volts have been observed and developed across a ten-foot-long section of buried ground conductor during a lightning strike to a microwave tower.

[1] SCTE/ANSI 226 section 6.1 Figure 1

The need to equalize surge potentials by specific classifications, groupings and terminations of the grounding system elements onto the master ground bar such as:

- P - Surge Producers
- A- Surge Absorbers
- N- Non-Isolated Ground Zone (IGZ) Equipment Grounds
- I - IGZ Equipment Grounds

There is a need to reduce potential differences and control surge currents between interfacing equipment racks using ground bars and an isolated ground zone (IGZ). It is important to provide ease of troubleshooting ground loops and other undesirable currents, when discovered on the grounding system. It is also important to better manage the individual conductors and ensure adherence to the specifications in a continuously changing electrical grounding system. Unlike the design criteria established for the exterior grounding system installation, there is no single acceptable numerical value of resistance or impedance for the interior grounding system.

For new critical facility installations or expansions GR-295 mesh grounding ***shall*** be used. The Mesh–BN reinforces the common building network (CBN).

CBN is the principal means for effecting bonding and grounding inside the critical facility. It is the set of metallic components that is intentionally interconnected to form the principle building network (BN) in a building. These components include structural steel or reinforcing rods, metallic plumbing, AC power conduit, alternating current equipment grounding conductors, cable racks, bonding conductors and possible incidental metal interconnections. The CBN typically has a mesh topology and is connected to grounding electrode system.

The critical facility main ground ring ***shall*** follow the communication trays. Interior ground ring ***shall*** be insulated #2/0 AWG. offsetting bracket/mount to be utilized on the outside of the tray, supported by the communication trays to avoid running the ground cable through the tray. These brackets ***shall not*** be utilized to satisfy any bonding/grounding requirements.

Other conductive trays ***shall*** be bonded to main ground ring using #6 AWG.

Racks ***shall*** be bonded at the top of rack with #6 AWG jumper cable to the main ground ring.

Ladder / basket tray sections ***shall*** be bonded using jumper cable, #6 AWG max 12” length.

8.3. Conductor Sizing, Routing and Termination

Grounding conductors are the conductors used to connect equipment or the grounded circuit of a wiring system to a grounding electrode or grounding electrode system. These conductors *may* be the wires that connect grounding electrodes together, form buried ground rings, and connect objects to the grounding electrode system.

All external grounding conductors ***shall*** be bare tinned solid or stranded #2 AWG or larger copper wire. Solid wire is recommended below grade to prolong longevity. For areas highly prone to lightning and/or areas with highly acidic soil, larger conductors *should* be considered.

Solid straps or bars *may* be used as long as the cross-sectional area equals or exceeds that of the specified grounding conductor.

8.3.1. *The following requirements apply when installing grounding conductors:*

Grounding conductors *should* be run as short, straight, and smoothly as possible, with the fewest possible number of bends and curves. Sharp bends ***shall*** be avoided because the sharp bend increases the impedance and might produce flash points. See Figure 3.

Ground conductors of all sizes ***shall*** maintain a minimum bending radius of 8 inches. The angle of any bend ***shall not*** be less than 90° (per NFPA 780; Article 4.9.5).

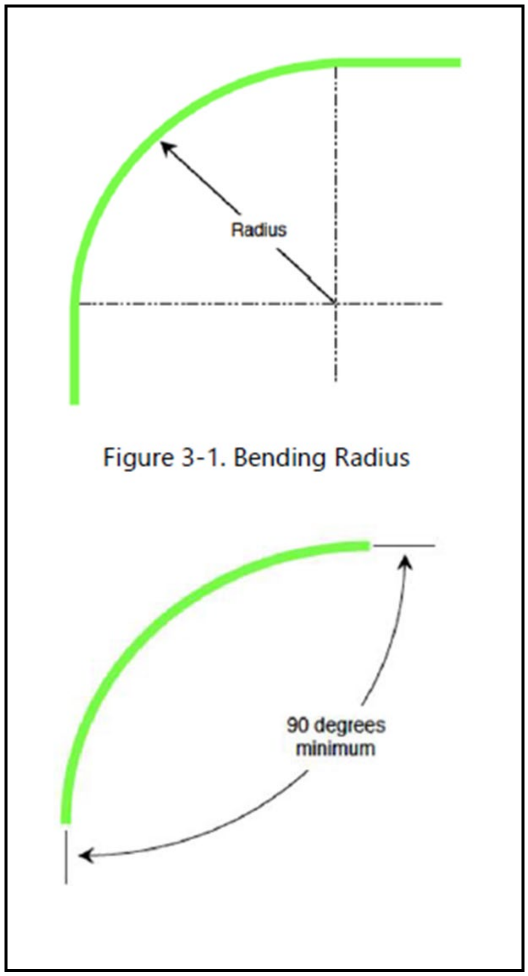

Figure 3-1. Bending Radius

Figure 3 - Bending Radius and Angle of Bend

Grounding conductor sizes are based on a resistance criterion established for the critical facilities. Therefore, the approximate length of each grounding conductor installation *should* be known prior to attempting to size the specific conductor. Figure 4 shows the required grounding conductor size for the 0.005 ohms and 0.01 ohms resistance criteria. This chart will be the only standard needed for sizing most grounding conductors in a critical facility. The only exception will apply to grounding conductors that terminate to DC and AC power distribution enclosures, for example, battery distribution circuit breaker bays and battery distribution fuse bays (BDFBs, BDCBBs) or AC power panels. The conductors terminated to power distribution enclosures will require the further application of Table 1, which considers the rating of the circuit protective device upstream of the enclosure in the power distribution circuit. Grounding conductor routings *should* be made in a manner which minimizes sharp bends in the conductors or terminations. Square corners, typically used in DC power conductor routing, *should not* be made. Rather, grounding conductors *should* have gradual bends with a minimum bending radius of eight inches. When grounding conductors are required to be routed in conduit, nonmetallic (PVC) conduits *should* be used, whenever possible. All metallic supporting devices used to secure the PVC conduits *should* be installed in such a manner that they do not create a metallic encirclement around the PVC. Nylon bolts and/or washers *should* be used to break any metallic encirclements. If PVC conduits are not permitted by code, and metallic conduits are required, these conduits ***shall*** be bonded to their respective grounding conductor at both the feed and return end of the power system. Daisy-chaining of bonds to neighboring conduit ***shall not*** be performed. All connections to copper ground bars *should* be made using long barrel, compression type, two-hole lug connectors.

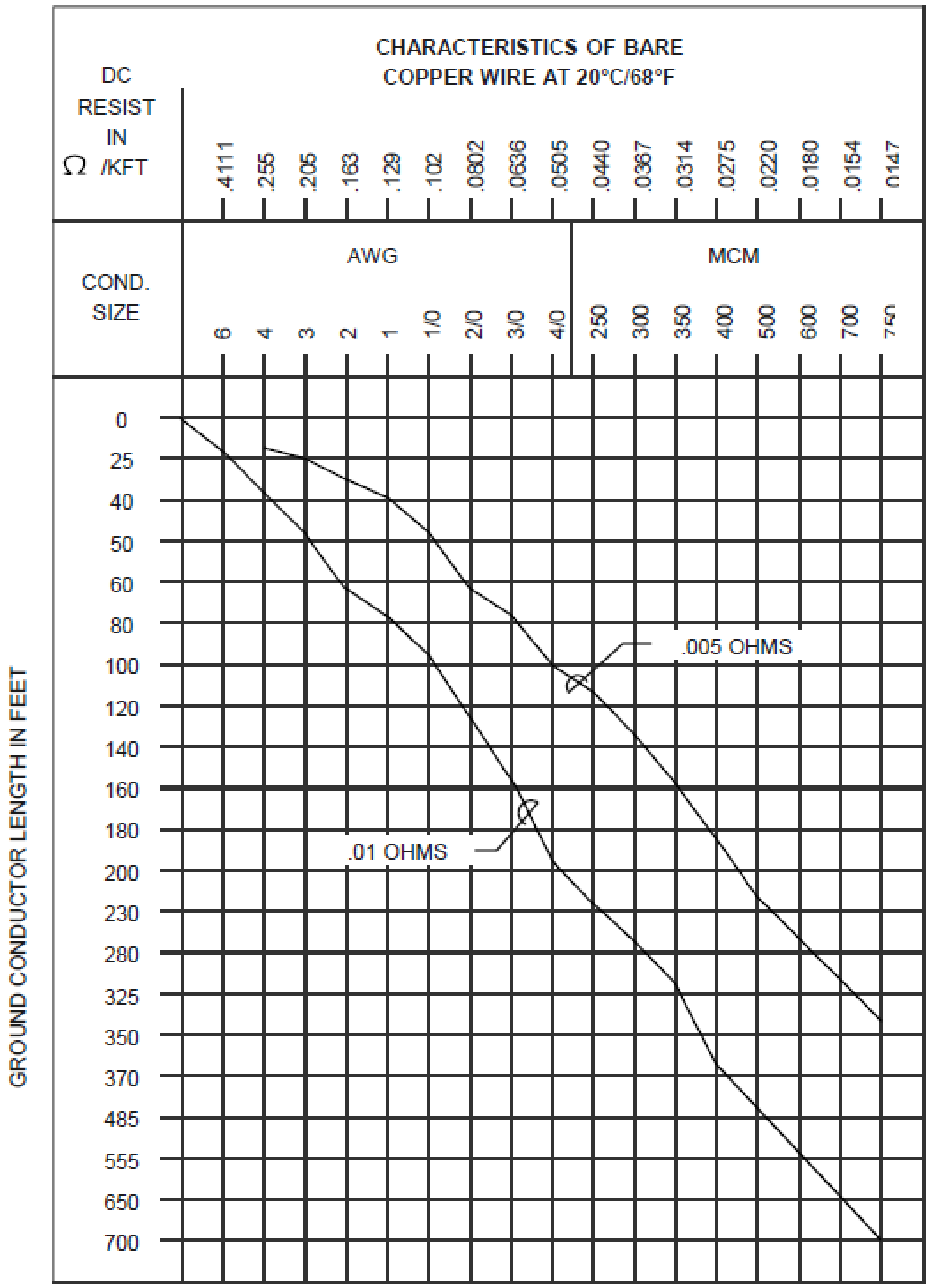

Figure 4 - Ground Conductor Sizing

Table 1 - Grounding Conductor Sizing[2]

Minimum Sizes (AWG/MCM) of Bonding Conductor Equipment to Frame

Rating Of Over current Device - Amperes	Size of bonding Copper Conductor AWG up to 50 ft length	Size of bonding Copper Conductor AWG up to 100 ft length	Note:
Signal cables	Same capacity of shielding wire size	NA	CEC 54-300 – (4)
Less than 20 A	Equal to BR cable	NA	GR 295
20	14	14	CEC table 16
30	12	12	
40	10	10	
60	10	10	
100	8	6	
200	4	3	Table 5-2 GR 295
300	3	1	Table 5-2GR 295
400	2	1/0	Table 5-2 GR 295
500	1	3/0	Table 5-2 GR 295
600	1/0	4/0	Table 5-2 GR 295
800	2/0	250 MCM	
1000	3/0	350 MCM	
1200	4/0	500 MCM	
1600	250 MCM	700 MCM	
2000	350 MCM	1000 MCM	

8.3.2. Securing Grounding Conductors

External grounding conductors, especially copper straps, are exposed to movement by wind and other physical forces that can lead to damage or breakage over time. The following requirements ***shall*** apply when installing grounding conductors:

The grounding conductor or its enclosure ***shall*** be securely fastened to the surface on which it is carried. Grounding conductors ***shall*** be attached using nails, screws, bolts, or adhesives as necessary. The fasteners ***shall not*** be subject to breakage and ***shall*** be of the same material as the conductor or of a material equally resistant to corrosion as that of the conductor. Industry best practices for surface treatment, choice of bonding materials, bonding, and protection ***shall*** be observed for the connection of dissimilar metals. Grounding conductors ***shall*** be securely fastened at intervals not exceeding 3 ft. (see NFPA 70, Articles 250-64(b), 810-21(c), and NFPA 780).

[2] NEC table 250.122

8.4. Master Ground Bar

The master ground bar (MGB)is the single termination point for all internal ground bus conductors, internal perimeter ground bus conductors, or equipment grounding conductors as described in this Section. All equipment and ancillary support apparatus within the critical facility system equipment area ***shall*** be bonded to the MGB. This MGB typically serves as the single point ground termination. A typical MGB with mounting brackets is shown in Figure 5.

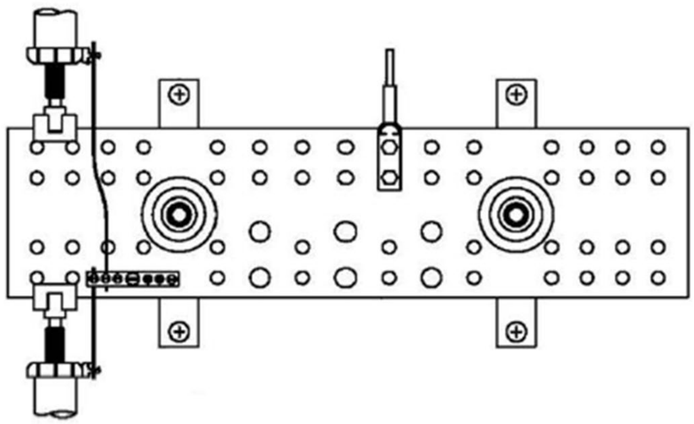

Figure 5 - Typical Master Ground Bus Bar

A single MGB ***shall*** be installed at all critical facility system equipment locations in a shelter, building, room, or area. An MGB *may* also be installed in an assembly of broadband equipment cabinets as deemed necessary to ensure an effective bonding point for all equipment grounding conductors.

A single rack, cabinet, or chassis that is not part of a critical facility and does not constitute part of a broadband system does not require the installation of an MGB as defined in this Section.

In this application, the single point where all equipment ground connectors terminate *may* be a point within the single cabinet or a point on the grounding electrode conductor immediately adjacent to the equipment rack, cabinet, or chassis as shown in Figure 6. Figure 7 is an example of a master ground bus bar connection configuration.

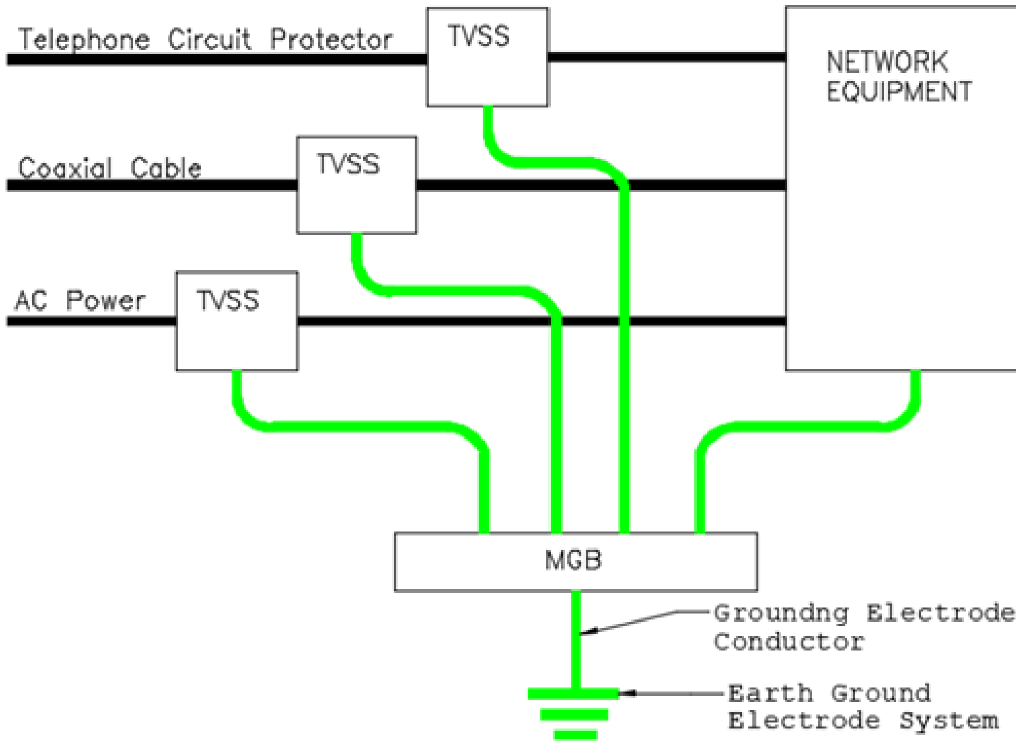

Figure 6 - Single Equipment Grounding Connections

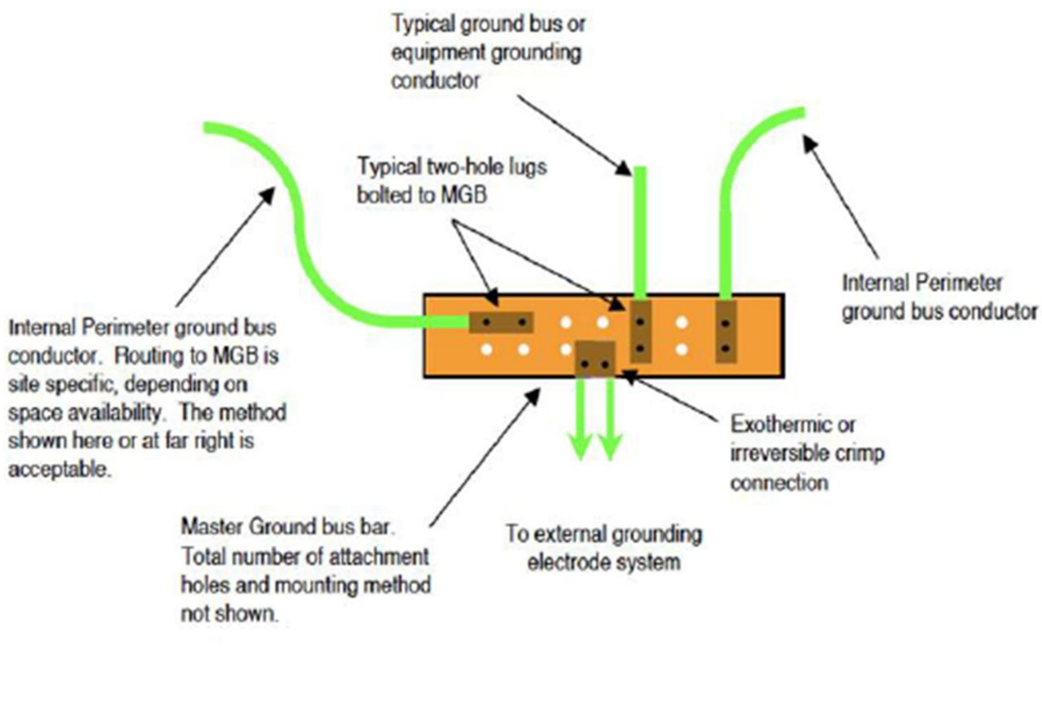

Figure 7 - Example of Master Ground Bus Bar Connection Configuration

Critical facilities ***shall*** have two grounding conductors that extend from the MGB to the external ground electrode system.

The MGB ***shall*** be mounted on insulated standoffs to the wall and *should* be mounted in close proximity to the electrical service equipment. The main electrical service disconnect supplying power to the critical facility *should* be located within close proximity to the MGB and ideally along the same wall. This enables a single point bonding of the electrical service and the MGB grounding electrode conductor to the grounding electrode system.

The MGB ***shall*** meet the requirements of Table 2.

Table 2 - MGB Requirements

Item	Specification
Material	Bare solid copper bus bar or plate of one-piece construction. May be electrotin-plated
Minimum Dimensions	Width: 24 in. Length: 6 in. Thickness: 1/4 in.
Mounting brackets	Must be suitable for the application
Insulators	Polyester fiberglass 15 kV minimum dielectric strength flame resistant per UL 94 VO classification
Conductor Mounting Holes Number Dimensions	Dependent on number of conductors to be attached. Holes to be 7/16 in. minimum on 3/4 in. centers to permit the convenient use of two-hole lugs.
Allowable bonding methods	Exothermic welding Irreversible crimp connection Other suitable irreversible crimp connection process

8.5. Frame and Equipment Grounding

Main aisle feeder ground conductors can be used to run along a series of rows and the conductors *should* be sized per Figure 4 to maintain a resistance of less than 0.01 ohms to ensure proper operation of circuit protection (aka circuit protective) devices.

Row aisle feeder ground conductors, which are the aisle feeder ground conductor grounds that run down each row of cabinets/racks, ***shall*** be bonded with a parallel tap to the main aisle feeder ground conductor, and *should* be a minimum #2 AWG**.**

All aisle feeder ground conductor grounds *should* have end caps. Cabinet/rack frame ground conductors are tapped off the row aisle feeder ground conductors, and *should* be a minimum of #6 AWG, one dedicated to each cabinet/rack, not doubled-up or daisy-chained, and *should* terminate within the cabinet/rack to a cabinet/rack frame ground bar.

Each cabinet/rack frame ***shall*** be grounded using a frame ground bar (dedicated 1" x ¼" copper ground bar of sufficient length) to maintain a separation of dissimilar metals and to facilitate conductor attachment. Note that some legacy sites might not have a cabinet/rack frame ground bar. See Figure 8.

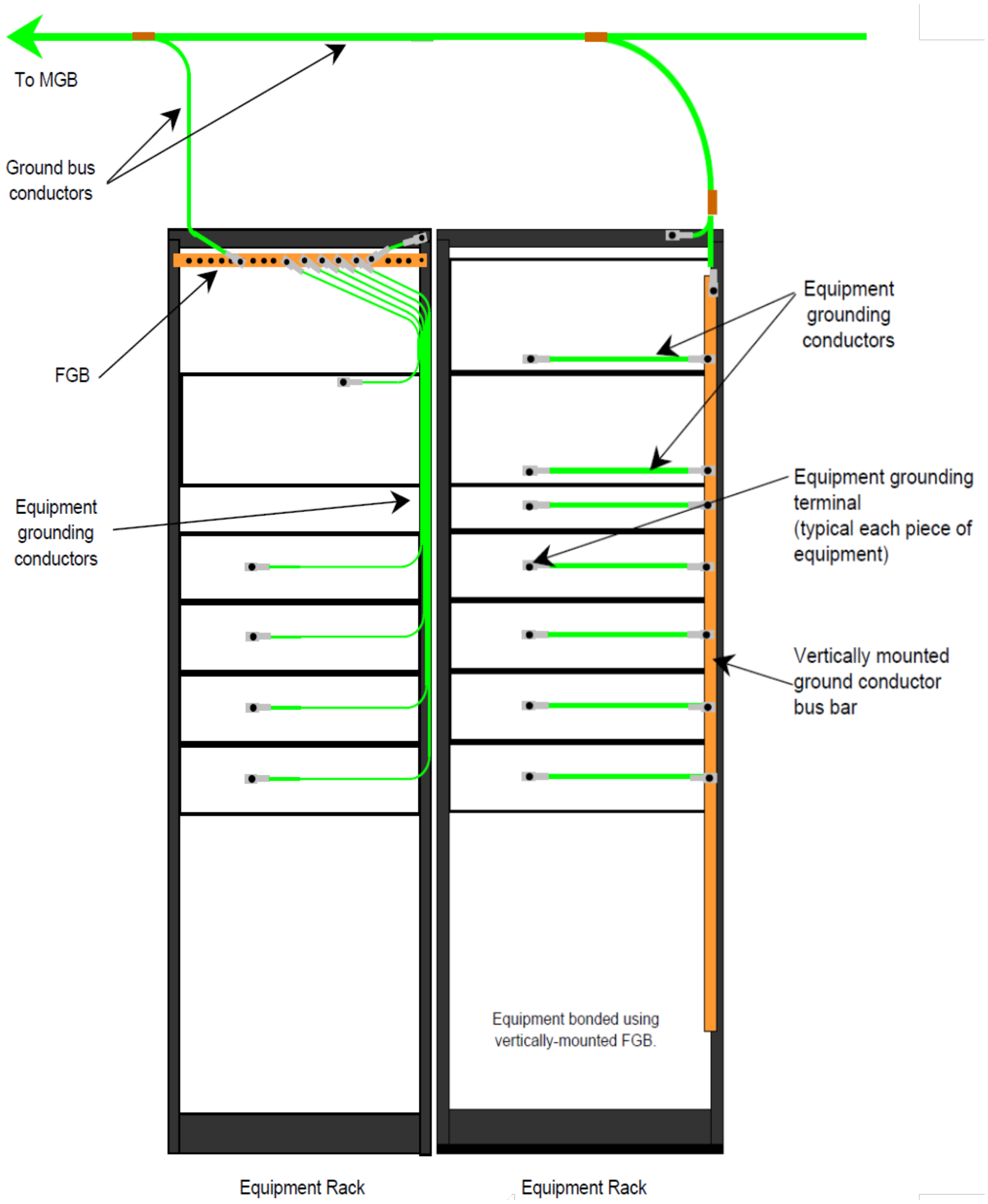

Figure 8 - Frame Grounding

Figure 9, Figure 10, and Figure 11 contrast acceptable and unacceptable frame grounding methods. While some of the figures show acceptable grounding scenarios with the absence of a dedicated frame ground bar, be advised that this is not the preferred scenario. All new installations ***shall*** be done as shown in Figure 9.

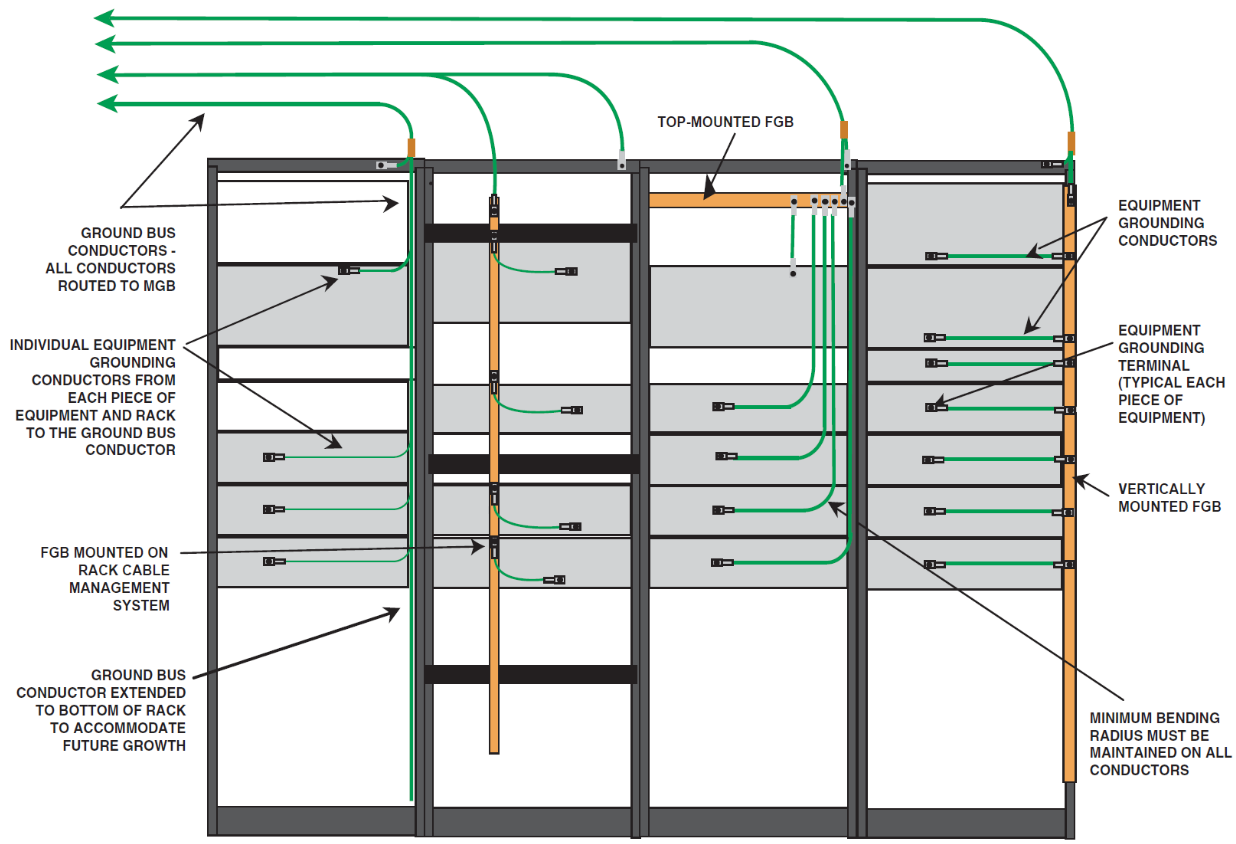

Figure 9 - Acceptable Methods for Bonding the Equipment to the MGB / SGB

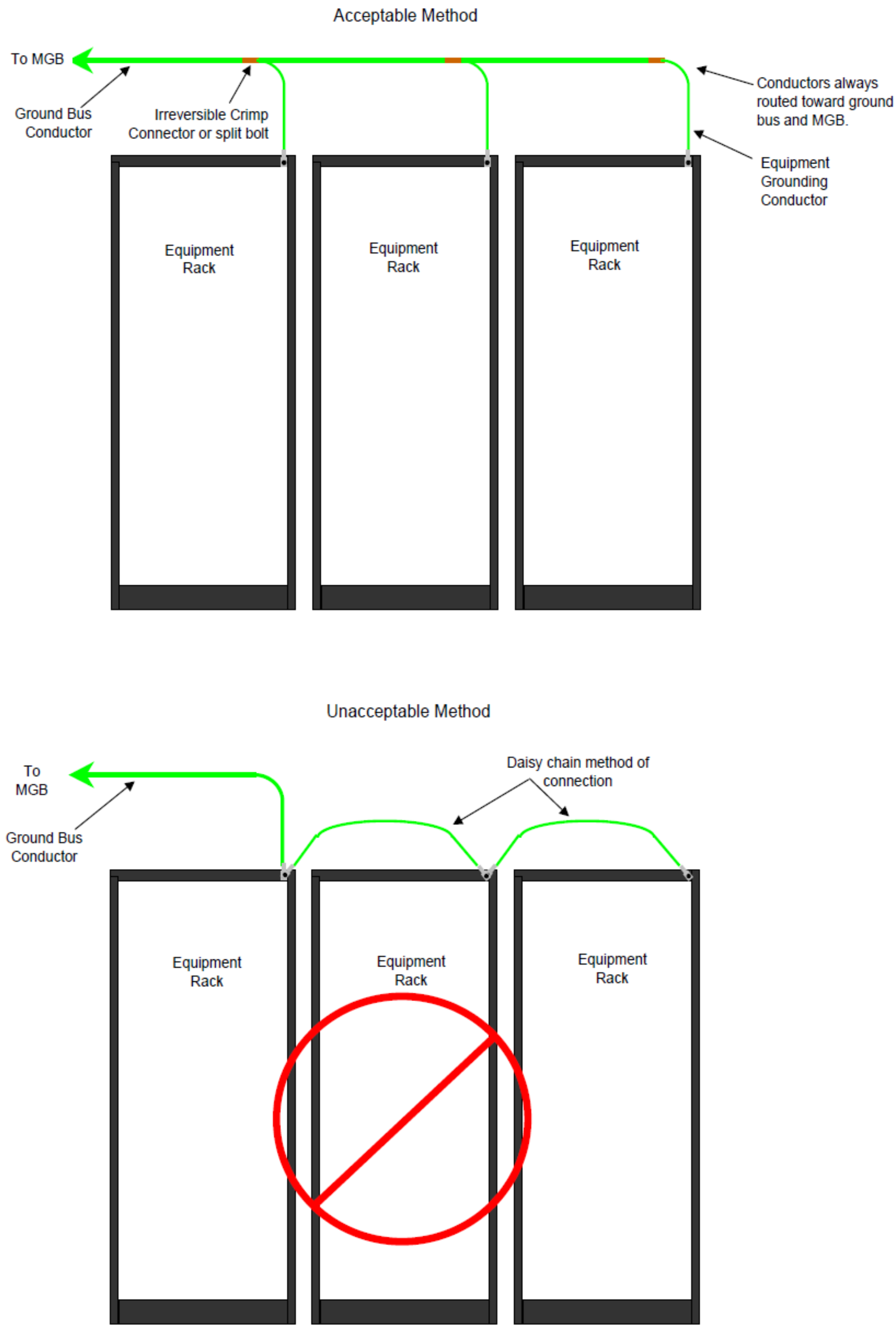

Figure 10 - Acceptable and Unacceptable Frame Grounding Methods

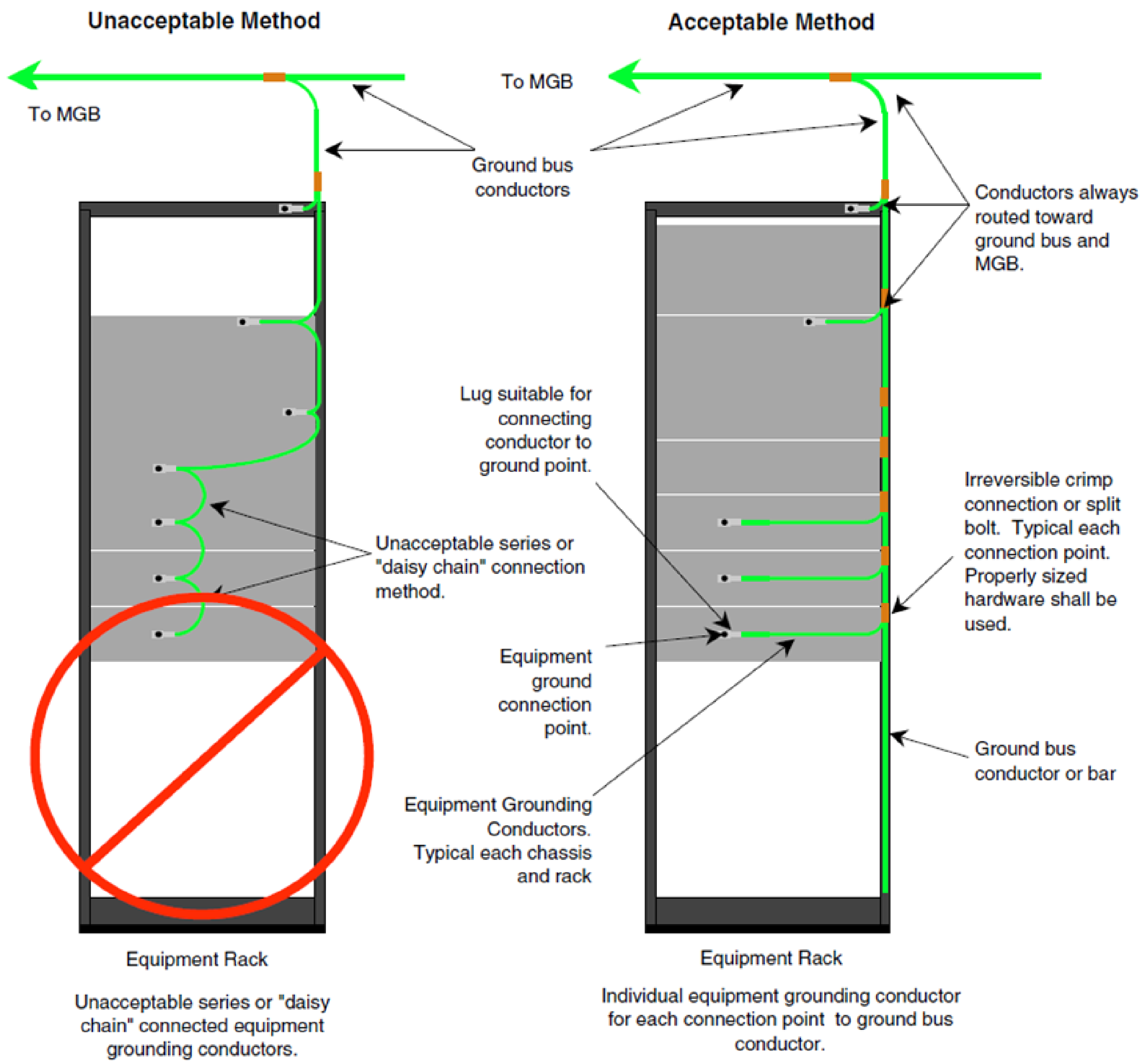

Figure 11 - Acceptable and Unacceptable Frame Grounding Methods

The frame ground bar *should* have connections to each of the provided equipment chassis grounds, and a minimum of one connection to the cabinet/rack. Doubled-up or daisy chained connections ***shall not*** be allowed.

All ground connections *should* be made using two-hole lugs. At the chassis ground level, however, single-hole ground bars are often the only option available (typically for #10 AWG and smaller). For single-hole connections, a serrated (external-tooth) washer *should* be used.

Before making frame ground connections, any paint *should* be scraped off & a thin coat of 'NO-OX-ID' or similar anti-oxidation compound *should* be applied**.**

8.6. Cable Entrance Grounding

The coax, telephone and fiber cables will also subject the facility to transient currents associated with ground potentials often developed external to the facility, but which enter the facility through the cable shields and metallic support members. These shields and support members *should* be terminated as close to their facility entrance locations as possible. In addition to the shields, the copper pair conductors will also have surge protectors which ***shall*** be grounded inside the facility. To effectively ground these shields, metallic support members and surge protectors, a ground bar or bars *should* be installed at the service entrance locations for these incoming cables. This bar or bars *should* be connected to the producer section of the MGB, where applicable, using an appropriately sized copper conductor.

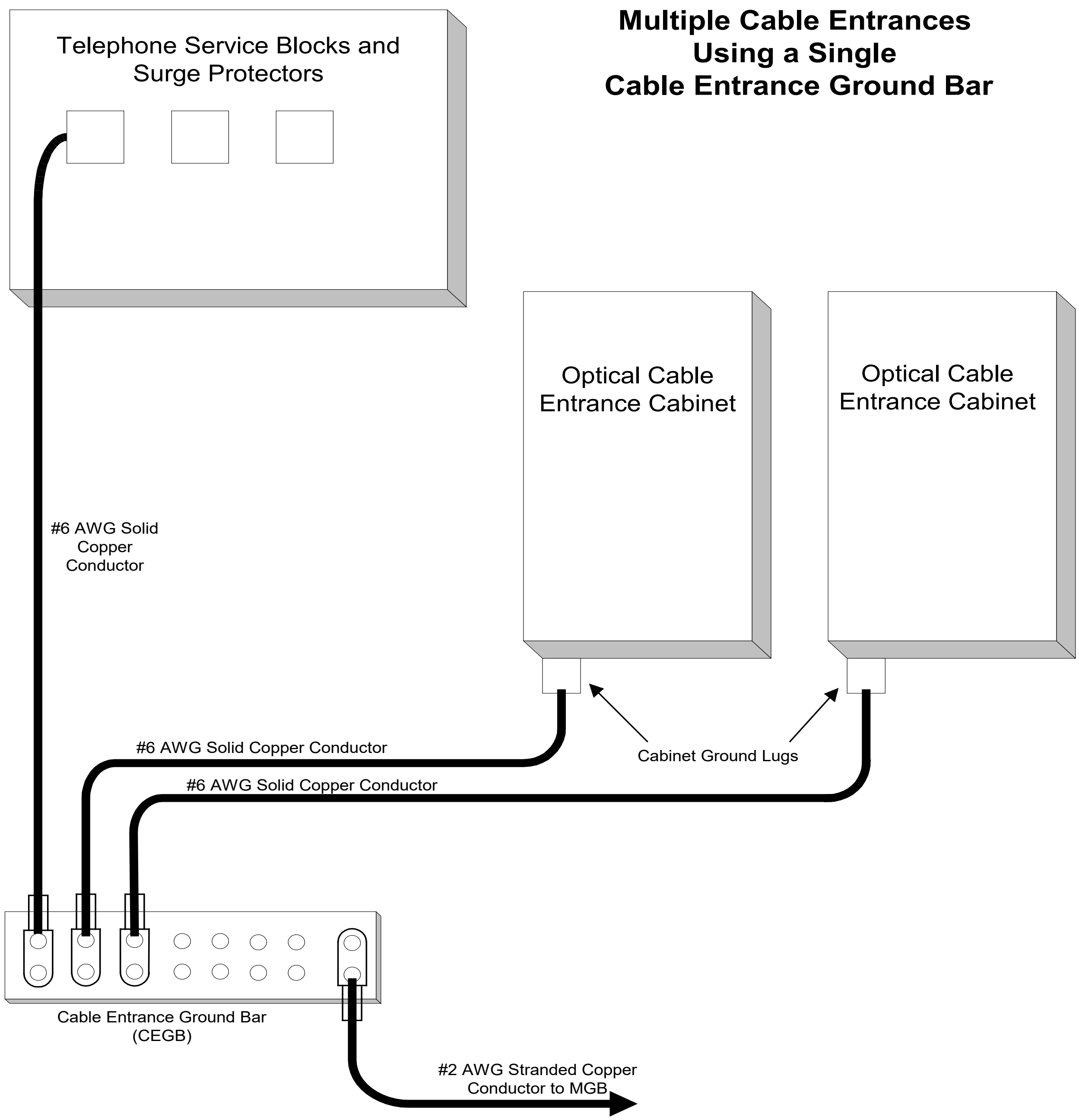

Figure 12 - Multiple Cable Entrances Using a Single Cable Entrance Ground Bar

The number of cable entrance ground bars *should* be determined by the physical location of the various cable entrances. If all cables enter the facility at one central location or room, then one cable entrance ground bar *should* suffice for all. If entrances are not located in the same area, then two or three cable entrance ground bars *may* be installed. Each of these bars *should* be connected to the MGB, as well as to their respective shields, surge protectors and associated equipment racks and cabinets which are in their respective rooms. Many sites have multiple fiber entry cabinets (FEC) which contain provisions for grounding metallic shields and support members. Ensure that they are properly grounded to the cabinet interior ground bar and the cabinet itself. Newer OSP fiber cables might have Kevlar support members, which do not need to be grounded, but the cable shields still do.

There ***shall*** be a single integrated cable service entry connection point constructed of solid copper and electrically continuous between the interior and exterior of the structure. The service entry connection point *may* provide a means for termination of the grounding bus and equipment grounding conductors and *may* be used as the internal and external ground bus bar.

8.6.1. External Ground Bus Bar

The purpose of the external ground bus bar (EGB) is to provide a convenient grounding (earthing) termination point for antenna transmission lines (coaxial cables) and other cables prior to their entry into a building or shelter (ANSI TI.313) to their point of entry into the building or shelter (NFPA 70-2020, articles 770.93, 800.100, 10.20, 820.93, and 820.100).

Requirements for external ground bus bars, when used, are listed below:

- The EGB ***shall*** be designed for the purpose of grounding and *should* be UL listed,
- The EGB ***shall*** be installed at the point where the antenna transmission lines and other communications cables enter the building or shelter.
- The EGB ***shall*** be connected directly to the grounding electrode system
- Connection of the grounding electrode conductor to the EGB ***shall*** use exothermic weld or listed irreversible compression connections (ANSI T1.313-2003).

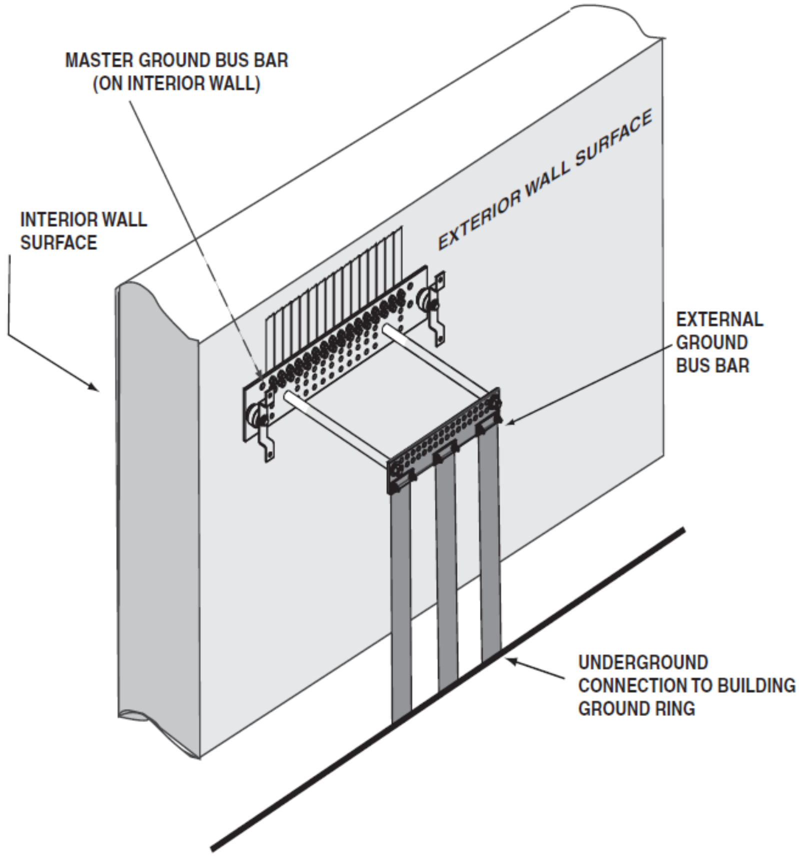

Figure 13 - External Ground Bus Bar

8.7. Main Utility Service

Grounding requirements for the main AC service switchboard (MSS) are consistent with, and often exceed, those required by the National Electric Code (NEC). The incoming neutral conductor, typically from the local utility, is terminated onto an insulated neutral bus bar mounted inside the MSS. At that point, a conductor or bus bar is used to bond the neutral to the enclosure mounted (non-insulated) ground bar. The neutral bus bar *should not* have any other grounding connections other than this neutral to ground bond. The ground bar inside the MSS is then required to have copper grounding conductor connections to building steel and/or rebar, the cold-water pipe (if metallic) and a driven rod system (building ground ring). An addition, it is recommended that a copper grounding conductor be connected to the MGB. Minimum sizing requirements for the national electrical code-required conductors can be found in the current code book.

Copper wire, busses and other conductors and terminals ***shall*** be used for all power system grounding. The use of aluminum wiring is prohibited. The ground wire between any AC powered device and the panel board ***shall*** be a continuous copper conductor with a type THHN green insulation, and properly bonded per the appropriate code authority. Ground wires ***shall not*** be to ENT (electrical nonmetallic tubing) conduit, nor will the conduit be used as the sole ground conductor. All metallic conduit steel bonding bushings installed on both near and far ends ***shall*** be installed only per appropriate code authority standards. All metallic conduits larger than 1” in diameter ***shall*** have metallic bushings installed on both near and far ends. Plastic conduit bushings are appropriate for PVC but are prohibited on metallic conduit.

8.8. Standby Generator

The internal standby generator frames ***shall*** be connected to the MGB. The external standby generator frames ***shall*** as a minimum be connected to the exterior ground ring and optionally to the MGB. These connections *should* be minimum #2 AWG copper or larger. The connection to the MGB *should* be located on the surge producer section of the bar, if applicable. If the two 2/0 connections are made to the generator skid, then a 2/0 bonding jumper is required between the skid and the generator frame The standby generator neutral ***shall*** be bonded to ground, either inside the generator tap enclosure or through the MSS neutral to ground bond.

If the feed from the generator to the automatic transfer switch (ATS) is a three-wire feed (i.e. does not contain a neutral conductor), then the generator neutral ***shall*** be bonded to ground inside the generator tap box. If the feed from the generator to the ATS is a four-wire feed (i.e. contains a neutral conductor) and the ATS is a three-pole device (neutral is not switched), then the generator neutral cannot be bonded to ground inside the generator tap box. It will need to establish its neutral to ground bond inside the MSS through its continuous neutral conductor connection between the generator and the MSS.

If the feed from the generator to the ATS is a four-wire feed (i.e. contains a neutral conductor) and the ATS is a four-pole device (neutral is switched), then the generator neutral ***shall*** be bonded to ground inside the generator tap box.

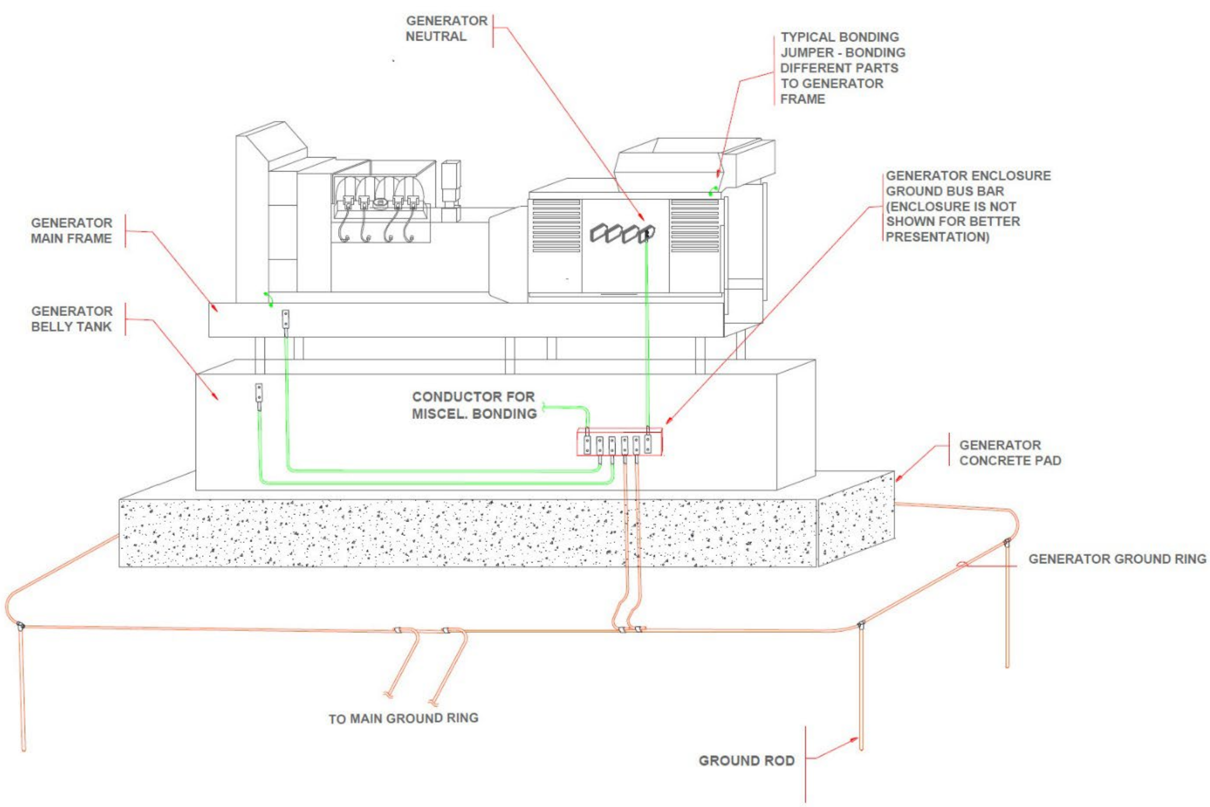

Figure 14 - Four-Pole ATS Generator Installation

8.9. Uninterruptable Power Supply

Uninterruptable power supply (UPS) System grounding requirements are also relatively simple in that a properly sized grounding conductor connection is required between the UPS module internal ground bar and the MGB. The connection to the MGB *should* be located on the surge producer section of the bar if so equipped. In addition, and if the module's battery cabinet or rack is external to the module enclosure, an insulated #6 AWG stranded copper conductor ***shall*** be installed between the module ground bar and the battery rack.

The UPS module or modules produce a separately derived system which, by the appropriate regulatory authority, typically requires that its output transformer neutral be bonded to ground. The UPS's output transformer neutral ***shall*** be bonded to ground inside of the module output section, or it can establish it's neutral to ground bonding through the upstream MSS neutral-to-ground bond. The UPS cannot have two such bonds. Normally, the module will be bonded to ground inside the module output section unless there is an external maintenance bypass cabinet. If there is an external maintenance bypass cabinet, the external bypass feed *should* contain a neutral conductor which connects back to the MSS switchboard neutral. In this case, the module ***shall not*** be bonded inside its output section (i.e. neutral ***shall*** be isolated from ground) and it ***shall*** rely on the MSS neutral to ground bond.

8.10. Network Equipment Grounding Connections

Grounding requirements for network equipment installations are predominantly dictated by the specific equipment manufacturer. Grounding connections ***shall*** conform to the equipment manufacturer's requirements.

8.11. DC Plant

When grounding DC power plants several factors *should* be considered.

For example, when dealing with a negative 48-volt DC system, the positive ("return") bus bar inside the main DC power board requires a ground reference connection. This ground reference connection ***shall*** be chosen to be of appropriate size to handle the necessary current requirements. Like the MSS neutral bus bar grounding requirements, the DC power plant's positive ("return") bus ***shall not*** be bonded to ground anywhere else on its distribution system. Therefore, the DC positive bus ***shall*** be isolated from all DC powered equipment racks and power distribution boards. The following items ***shall*** be bonded with an equipment grounding conductor.

- DC distribution board enclosures
- Battery racks
- Rectifier enclosures
- DC disconnect switch enclosures

There *may* be frame ground "collector" bars that *may* connect various groups of equipment to the master ground bar.

8.12. Cable Ladder

Cables ladders support the DC power conductors and communication signal or network cables as they are routed between power distribution boards, and various equipment racks. These ladder sections ***shall*** be bonded to each other and master ground bar (possibly via auxiliary ground bars) to ensure a continuous ground path in the event a power conductor becomes shorted to the ladder. The bonds ***shall*** be made using #6 AWG stranded copper conductors or braided tinned copper jumpers. It is preferred that when using #6 stranded copper conductors that these conductors have green insulation for identification purposes.

It is considered good practice for conductors to be crimp-connected at both ends and bolted through the cable ladder. All paint *should* be removed from the points of contact on the cable ladder. In addition, each level of cable ladder *should* be connected to an insulated #6 AWG, stranded copper conductor that is connected to the ladder section at one end and then crimp connected to an insulated 2/0, stranded copper conductor at its other end. Functionally equivalent methods *may* be used.

8.13. Raised Floor

If a raised access flooring system is installed in the critical facility equipment room, grounding connections to the raised floor grid ***shall*** be provided. These connections ***shall*** be made via a #6 AWG stranded copper conductor or larger that is run along and underneath the access flooring (in at least two directions) and attaches periodically to the metallic pedestal along its run. The connections to the pedestals ***shall*** be made using a listed clamp suitable for raised floor pedestal applications.

A common ground point ***shall*** be provided for any metallic infrastructure that shares the underfloor space of the raised access flooring system. This common grounding point ***shall*** be bonded to the grounding system for the raised access flooring system.

8.14. Use of Metallic Cold Water Pipes

The incoming metallic cold-water pipe ***shall*** be connected to the AC main service switchboard (MSS) ground bars and *may* also be connected to the MGB. Connections to the cold-water pipe ***shall*** be made ahead of the meter and a bonding jumper ***shall*** be installed across the meter or another insulated junction.

Other conductive structures within the facilities ***shall*** be bonded to the grounding system. These include metallic surfaces such as walls, doors, window frames, stairs, metallic frames or building envelopes, foundation re-bars, different pieces of equipment enclosures, trays and metallic conduits, metallic facility pipes, utility meters, tower frame, storage tanks, fuel tanks, and any other non-current carrying metallic structures not listed here.

8.15. Multi-Floor Buildings and Expansions

Multi-floor critical facilities involve telecommunication equipment physically located on separate floors. Because of the separate floor locations of this equipment a MGB extension system ***shall*** be installed to equalize potential (voltage) differences. This ***shall*** consist of a secondary (auxiliary) ground bar on each floor. These secondary ground bars ***shall*** be bonded to the building master ground bar and bonded to building steel.

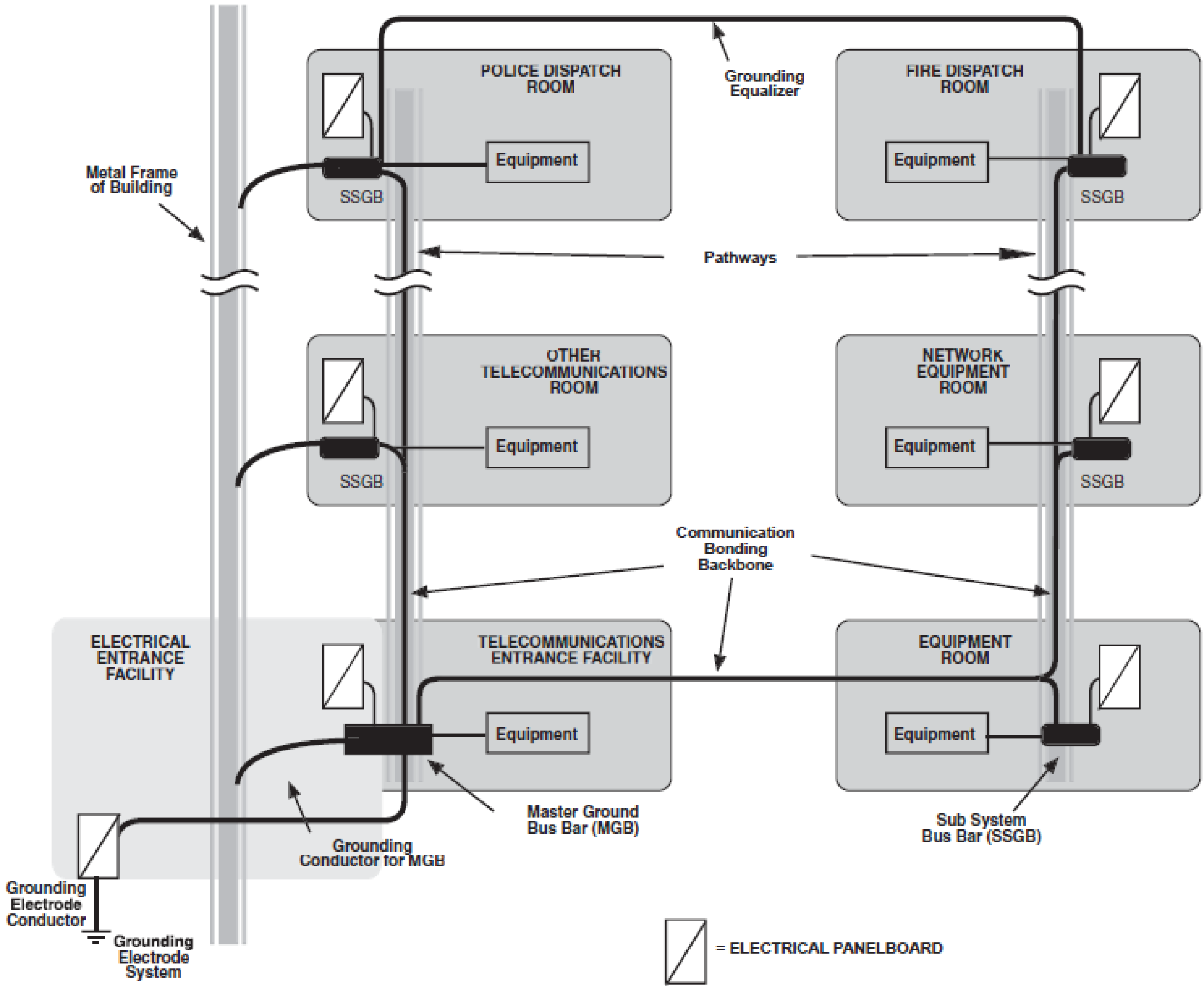

Figure 15 - Multi-floor Installations

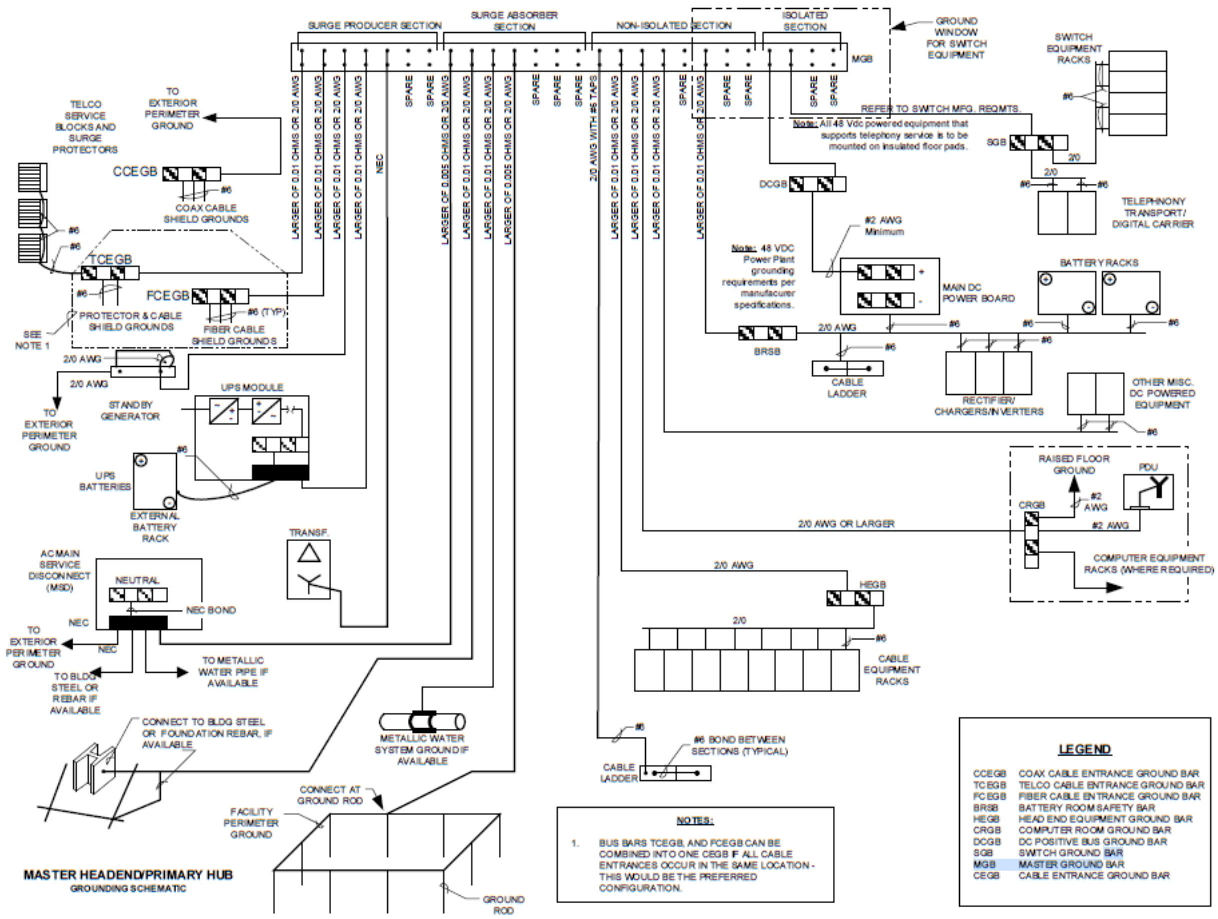

Figure 16 - Master Telecommunications Center Grounding Schematic

8.16. Materials Used for Grounding

Ground bars ***shall*** be made of ¼ inch thick solid copper with a pre-punched hole pattern. The ground bar ***shall*** be sufficiently wide to terminate all connections as well as provide room for future expansion. Acceptable sample MGB configurations are shown in Figure 17.

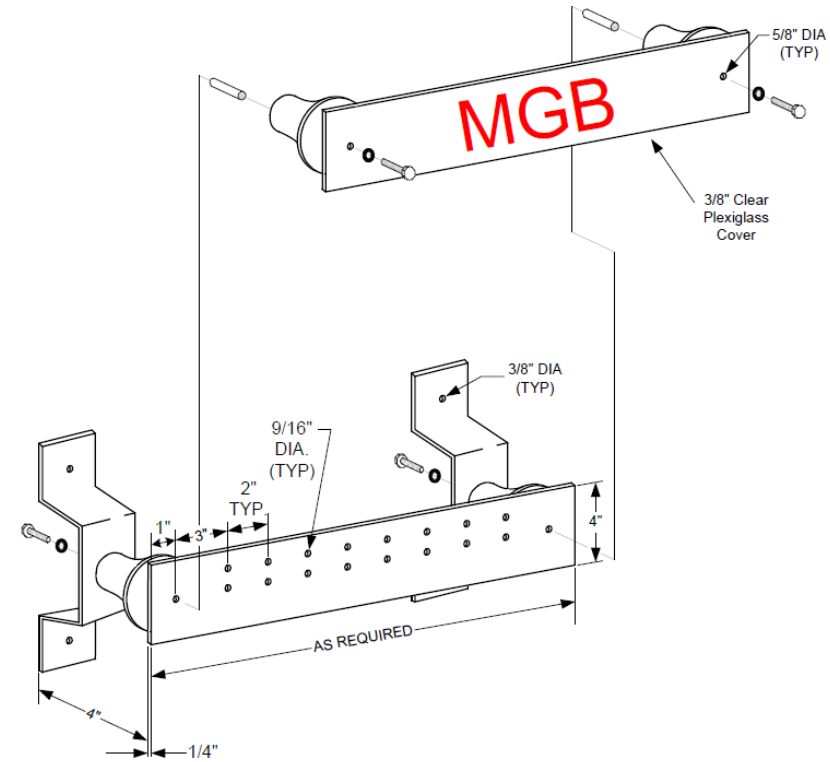

Figure 17 - Examples of Acceptable Ground Bar Materials and Measurements

Grounding conductor termination hardware *should* be stainless steel. Spring washers ***shall*** be used for all bolted connections to copper ground bars. Interior grounding conductors ***shall*** be insulated, stranded (Class B) copper conductors.

All such conductors *should* be labeled on both ends to indicate opposite end termination points for conductor runs. External buried connections ***shall*** be exothermic using connectors listed for buried use or *may* be mechanical when inside inspection wells. Internal connections to ground bars ***shall*** be made using long barrel, compression, two-hole lugs with inspection windows. Internal grounding connections between copper conductors *should* be made by type "C" compression connectors. An acceptable connector is illustrated in Figure 18.

Figure 18 - Acceptable Compression Connector

8.17. Ground System Testing

Periodic testing of the ground system *should* occur at least every five years. There are several industry standards that *may* be used for ground system testing. These include selective earth resistance testing and clamp-on testing. Testing results *should* be documented and retained for future reference. Testing results *should* be compared with previous results to identify and resolve any changes.

Internal grounding system testing is somewhat limited due to all the interconnections between grounded systems. It is possible, however, to verify single point grounding connections to isolated systems. For example, the isolation of the DC positive bus and the DC power equipment racks can be verified by measuring the DC current flowing in the grounding conductor connection to the DC power plant positive bus. Ideally, there *should* be no current flowing in this conductor. However, if several amperes of leakage DC current are found to be flowing in this conductor an investigation *should* be made as to the path of the leakage current. In addition, AC and DC current measurements *should* be made on all conductors terminating onto ground bars. These current measurements *should* be recorded on a schematic diagram of the grounding system for use in future comparisons. Copies of this schematic *should* be placed on file locally in a file marked "Ground System Current Readings".

9. Surge and Lightning Protection Systems

9.1. Surge Protection

Lightning strikes and utility switching surges can cause voltage surges on the incoming utility AC power feeders. To protect the facility from these voltage surges, a surge protective device (SPD) device is required to be installed at the main service switchboard (MSS) for each facility. The connecting leads *should* be kept as short as possible and there *should* be no severe bends in any of the leads. The SPDs *should* have internal fuses to isolate them from the power circuits if a device fails short. The SPDs device *should* have connections to all energized phases, neutral and ground bus bars inside the MSS.

In addition, all tower mounted lights ***shall*** have an SPD installed on the AC panelboard feeding the tower light. Some facilities *may* require the installation of additional SPD devices on the electric system as required by special circumstances. These additional devices *may* be required in high lightning activity areas and areas where the power grid is subject to voltage transients. The SPDs would normally be installed on the generator output panelboard, or ATS, and at the panelboard at the input feeder to a UPS module. These additional devices *should* coordinate with the upstream devices described above where their installation is deemed necessary.

9.2. Roof Mounted Lightning Protection

All facilities must be compliant with all appropriate local lightning standards. In North America these include but are not limited to NFPA 780 GR1089 and CSA B72.

The roof mounted lightning protection system *should* connect to the building buried ground ring through down lead conductors spaced in accordance with all appropriate local lightning standards. In North America these include but are not limited to NFPA 780, GR1089, and CSA B72.

10. Environmental Handling for ESD Sensitive Devices

Static electricity is created by the accumulation of stationary electrical charge on a body or conducting medium. As such it is a common phenomenon created by physical motion. Even circulating air currents can cause a charge build-up, especially during low humidity conditions. This electro-static charge build-up discharges whenever the charge storing medium meets ground. These static charges can store up to as much as 40,000 Volts during the normal course of a human body walking across a nonconductive floor in a low humidity environment. If exposed to electrical static charges of these magnitudes, the static sensitive electronic components contained in a critical facility can become permanently damaged.

To avoid damage of ESD sensitive devices the relative humidity (RH) *should* be ideally kept within the limits specified by ASHRAE TC9-9 and all manufacturer's requirements. Wrist straps *should* be used by all personnel handling printed circuit boards. ESD-rated grounded conductive floor tiles or mats *should* be installed near the base of each equipment rack. There *should* be wrist strap test stations at CF sites.

11. Commissioning and Maintenance

The commissioning of a facility's grounding and protection system installation ***shall*** be performed to ensure that the final installation meets or exceeds the original design intent so the facility will provide a safe and reliable environment for personnel and sensitive electronic equipment to operate. Commissioning is the act of visually inspecting all grounding system, lightning protection system, and surge arrester installations to verify that the electrical contractor has built these systems in accordance with the design engineer's drawings and specifications, as well as conformance with all applicable standards (including this one).

Typically, all power equipment enclosure covers are removed, all grounding conductor runs, terminations and routing are examined, all ground bars are inspected and all equipment grounding connections re-inspected during the commissioning of the system. In addition, current measurements are made in all conductor connections to the MGB. These currents will identify unwanted ground rings in the system. Ground rings in the building steel, cold water, AC power system, etc. are to be expected, whereas ground rings in the DC positive bus and switch frame grounding conductors are not expected nor are they desirable. In addition, grounding impedance measurements are made in the lightning protection down leads to verify that these leads are connected to the buried ground ring.

Consider using commissioning checklist from Cox/Charter as an Appendix?

11.1. Preventive Maintenance

Grounding system preventive maintenance is required to protect equipment/facility investments. Inadequate grounding, lightning protection, and the inevitability of internal and external power surges are the most likely reasons of equipment failures from unknown causes and are often incorrectly attributed to equipment defects instead of the root cause. As replaced equipment can fail repeatedly unless the root cause is determined, PM is required to identify the potential for ground and surge protection issues and identify these potential causes.

11.2. Safety

All electrical systems work ***shall*** be performed by qualified personnel in accordance with all appropriate local and national safety requirements.

12. Appendix (Informative)

The following is included for reference only. It is provided as an example of a typical operator checklist for grounding and bonding.

GROUNDING AND PROTECTION SYSTEM COMMISSIONING CHECKLIST

Name of Site: _________ **Location:**

Name of Inspector: _____ **Date:**

		YES	NO	N/A
A.	**Exterior Grounding System**			
1.	Were soil resistivity measurements made prior to the design of the grounding system?	☐	☐	☐
2.	Was the exterior grounding system design based on these soil resistivity measurements and the soil boring report?	☐	☐	☐
3.	Did the exterior grounding system resistance measurement meet the design criteria of 5 ohms or less?	☐	☐	☐
4.	Is there a properly sized (#2 AWG minimum) bare copper grounding conductor buried around the building?	☐	☐	☐
5.	Is this buried ground ring installed below the frost line or 30 inches, whichever is greater?	☐	☐	☐
6.	Are there ground rods attached to the buried ground ring at intervals as indicated on the construction drawings?	☐	☐	☐
7.	Does the buried ground ring have connections to building steel the MGB (2 connections), the MSS ground bar, generator enclosure frames, tower ground ring, cable entry hatch plate, and the roof mounted lightning protection system (if applicable) ?	☐	☐	☐
8.	Are all connections to the ground ring exothermic or approved compression type?	☐	☐	☐

		YES	NO	N/A
9.	Is there a security fence at this facility, and if so, is it grounded at every 50 feet interval?	☐	☐	☐
10.	Do these grounding connections to the fence terminate at the building or tower ground rings?	☐	☐	☐
11.	Are all outdoor lighting support structures grounded to a ground ring or driven ground rod?	☐	☐	☐
12.	Is there a tower installed at this site?	☐	☐	☐
13.	Does the tower have a ground ring, counterpoises, and grounding connections?	☐	☐	☐
14.	If a guyed tower, are the guy wires grounded?	☐	☐	☐
15.	Are the feed lines and ice bridge posts grounded properly?	☐	☐	☐
16.	Are the tower and building ground rings bonded together?	☐	☐	☐
17.	Have ground inspection/test wells been installed at all critical locations?	☐	☐	☐
B.	**Lightning Protection System**			
1.	Does this site have a roof mounted lightning protection system?	☐	☐	☐
2.	Does the installation meet NFPA 780 and has it been UL certified?	☐	☐	☐
3.	Do the down leads connect to the building ground ring?	☐	☐	☐
C.	**Interior Grounding System**			
1.	Is the MGB the correct size, mounting height, and location as shown on construction drawings?	☐	☐	☐
2.	Does MGB have correct pre-punched hole pattern and are all terminations two hole, compression lug type?	☐	☐	☐
3.	Are the following MGB conductor connections (as applicable) sized properly, tight, labeled and in their proper locations on the ground bar?	☐	☐	☐
	• Secondary Ground Bars (SGB/SSGB/FOG)	☐	☐	☐
	• Coax Cable Entrance Ground Bar (CCEG)	☐	☐	☐
	• Telco Cable Entrance Ground Bar (TCEGB)	☐	☐	☐
	• Fiber Cable Entrance Ground Bar (FCEGB)	☐	☐	☐
	• Standby Generator	☐	☐	☐
	• UPS Module Ground Bar	☐	☐	☐
	• All Dry Type Transformer Ground Bars	☐	☐	☐

	YES	NO	N/A
• AC Main Service Switchboard	☐	☐	☐
• Building Steel	☐	☐	☐
• Cold Water Pipe	☐	☐	☐
• Buried Ground Ring (2)	☐	☐	☐
• Headend Equipment Ground Bar (HEGB**)**	☐	☐	☐
• Miscellaneous DC Powered Equipment	☐	☐	☐
• Battery Room Safety Bar (BRSB)	☐	☐	☐
• DC Positive Bus Ground (DCGB)	☐	☐	☐
4. Does the MGB ground bar have a labeled polycarbonate (Lexan or Plexiglas) cover and stainless steel hardware?	☐	☐	☐
5. Does the MGB have spare termination locations for future use?	☐	☐	☐
6. Are cable entrance ground bars installed at the coax, Telco, and fiber cable entrance points into the facility?	☐	☐	☐
7. Are these ground bars properly labeled, installed in their proper locations and mounting heights, and does each have a properly sized grounding conductor connection to the MGB?	☐	☐	☐
8. Are the shields/protectors for all incoming coax, Telco, and fiber cables properly grounded to their respective ground bars?	☐	☐	☐
9. Does the Main AC Service Switchboard (MSS) have a neutral to ground bond?	☐	☐	☐
10. Have the following grounding conductors (NEC connections) been properly sized and connected to the MSS ground bar?	☐	☐	☐
• MGB	☐	☐	☐
• Exterior Ground Ring	☐	☐	☐
• Cold Water Pipe	☐	☐	☐
• Building Steel or Rebar	☐	☐	☐
11. Do the standby generators have properly sized grounding conductor connections made to the exterior ground ring and the MGB?	☐	☐	☐
12. Does the UPS module have a properly sized grounding conductor connection between it and the MGB?	☐	☐	☐

	YES	NO	N/A
13. Is the UPS module's output neutral bonded to ground inside the UPS output section and, if not, should it be?	☐	☐	☐
14. Does the 48 Volt DC Power Plant have a properly sized grounding conductor connection between it and the MGB?	☐	☐	☐
15. Are all battery racks, rectifiers, DC distribution power enclosures, and cable ladders properly grounded to a Battery Room Ground Bar (BRGB)?	☐	☐	☐
16. Have all dry type transformers been provided with a NEC sized grounding conductor connection to the MGB?	☐	☐	☐
17. Are there any requirements for AC isolated ground receptacles and, if so, are the appropriate AC panelboards equipped with isolated ground bars?	☐	☐	☐
18. Are all cable ladders bonded between sections and grounded to an appropriate ground bar?	☐	☐	☐
19. Is there a raised access floor system and is it grounded properly?	☐	☐	☐
20. If this site involves multi-floor equipment installations, are various floor SGBs bonded to building steel and the MGB?	☐	☐	☐
21. Are all grounding conductors sized in accordance with NEC?	☐	☐	☐
22. Are isolated grounding conductors installed in PVC conduits using non-metallic supports (or metallic supports with no metallic encirclements)?	☐	☐	☐
23. Are all ground bar terminations made using long barrel, compression type, two-hole lug connectors?	☐	☐	☐
24. Are all internal conductor-to-conductor terminations made using a type "C" compression connector with a plastic cover?	☐	☐	☐
25. Are all ground bars made of ¼ inch solid copper with pre-punched hole patterns?	☐	☐	☐
26. Are all ground bars installed with polycarbonate (Lexan or Plexiglas) covers with permanent labeling, and mounted on plastic-type insulators?	☐	☐	☐
27. Are all internal grounding conductors labeled on both ends?	☐	☐	☐
28. Has an approved SPD device been installed on the MSS switchboard?	☐	☐	☐
29. Are wrist straps installed on all electrostatic sensitive equipment racks?	☐	☐	☐
30. Measure and record AC and DC currents on each of the following MGB grounding connections (as applicable):	☐	☐	☐

	AC AMPS	**DC AMPS**
• Radio Equipment Ground Bar (REGB)		
• Coax Cable Entrance Ground Bar (CCEG)		
• Telco Cable Entrance Ground Bar (TCEGB)		
• Fiber Cable Entrance Ground Bar (FCEGB)		
• Standby Generator		
• UPS Module Ground Bar		
• All Dry Type Transformer Ground Bars		
• AC Main Service Switchboard		
• Building Steel		
• DC Positive Bus Ground (DCGB)		
• Buried Ground Ring (2 connections)		
• Headend Equipment Ground Bar (HEGB)		
• Battery Room Safety Bar (BRSB)		