How the New ANSI/SCTE 275 Grounding and Bonding Standard Can Improve Your Network Resiliency and Continuity

A Technical Paper prepared for SCTE by

Mike Glaser
Principal Engineer – Critical Facilities
Cox Communications
6305 Peachtree Dunwoody Road, Atlanta GA 30328
404-269-0143
mike.glaser@cox.com

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1. Introduction

Network reliability and resilience are usually only as effective as the weakest component in the entire network system. The words 'reliability' and 'resilience' are used in various industries, and have been used more frequently in recent years. They may have slightly different meanings depending on the context, but with respect to network systems, reliability means "it's there when we expect it to be". Resilience is a bit more multi-faceted; it means "how well are we prepared for, and how easily and quickly can we bounce back from extreme or prolonged events". Both require significant investments.

Another way to think of the relationship is this: reliability is the outcome and resilience is how you achieve that outcome. Reliability can be expressed as an availability key performance indicator (KPI), say 99.999% uptime, while resilience is all the detailed technical planning and design needed to achieve that, and for a critical facility, one of the main components is a good grounding and bonding system.

Knowing that critical facilities are foundational to the network and the delivery of lifeline telecommunications services, it is essential that all of their infrastructure systems are fully functional at all times. Cable operators always focus on maintaining robust and redundant systems, but how often do they overlook the proper grounding and bonding of these infrastructure systems?

A single electrical storm or utility surge can wreak havoc on network equipment in a critical facility, often creating significant performance issues that cost valuable time and money to repair, and can potentially result in a loss of customers. Human error also contributes significantly to these unfortunate, but largely avoidable consequences.

The proper grounding and bonding of electrical systems and network equipment in a critical facility is an indispensable element in the assurance of business continuity in the broadband and telecommunications industry, therefore high priority must be given to the grounding and bonding system from design and installation to commissioning and ongoing maintenance.

ANSI/SCTE 275 2021 brings together the best practices and cable industry expertise and experience, as it endeavors to guide cable operators in the deployment of grounding and bonding systems that will enable them to meet their reliability targets and ensure resilience of the network.

This paper will give an overview of the development and contents of the ANSI/SCTE 275 2021 standard, explain how it can improve network resilience, and provide some guidance on how best to deploy a grounding and bonding system that will ensure just that.

2. Development And Benefits Of The Standard

In early 2018, it was determined that cable operators could greatly benefit from an aggregation of grounding and bonding best practices at the very least, and perhaps even an industry standard in this area. A grounding and bonding task force was formed to explore the opportunities around various aspects of telecommunications grounding and bonding practices.

The task force met over a period of three years, and reviewed nearly 100 existing grounding and bonding standards currently being used by cable operators, as well as those from electrical, fire safety, and telecommunications carrier industries. There were contributions to the standard that eventually became ANSI/SCTE 275, "Electrical Grounding and Bonding for Cable Broadband Network Critical Facilities" from Cox, Comcast, Rogers, Shaw, and Charter.

There were a number of challenges, benefits and opportunities that came to light while this project was ongoing:

- Due to the varying histories, organizational compositions and customer services both common and unique to these cable operators, there were consequent variations in intent and approach, as well as the necessary level of detail, within the existing cable operator grounding and bonding standards. For example, there are inherent differences in the AC power and DC power grounding and bonding systems design, data center and headend design, vendor-driven requirements, and the hodgepodge of practices found in legacy acquisition sites. Additionally, the presence of a telephony switch would necessitate particular practices around isolated grounding specifications that are not present (or needed) in other critical facilities.

- To assist with collecting and aggregating the similarities and differences between cable operator specifications, a 'matrix' document comparing the specific practices and requirements (or lack thereof) in each grounding and bonding category (or sub-category) for each cable operator was developed and maintained.

- ANSI/SCTE 275 is the first grounding and bonding standard specifically developed for cable operators in the telecommunications industry. It brings together the best practices from various industry sectors, and outlines minimum standards for ensuring network reliability and continuity of cable operators service delivery to customers.

- Additional benefits of ANSI/SCTE 275 are as follows:

    - It lays the groundwork for safety and reliability, and is a key component to the resilience of critical facilities in all grounding and bonding system lifecycle phases - from the engineering design phase, through installation, then on to commissioning and periodic maintenance. By following this standard, cable operators can help assure business continuity.

    - The standard can be used to ensure vendors are using a standardized approach to grounding and bonding systems through each of the lifecycle phases.

    - A commissioning checklist is included in the appendix, which can assist engineering and operations staff with ensuring the grounding and bonding system is properly installed.

    - Proper grounding and bonding are foundational to personnel safety and network reliability, yet it is often the least understood system in a critical facility. ANSI/SCTE 275 will be able to be used as an educational tool for engineers and technicians, and better enable them to ensure continued reliable operation of all infrastructure systems within the critical facility.

3. Main Purposes Of Grounding And Bonding

The main purposes of grounding and bonding in general, and at a high level, are all about safety of personnel and reliability of network and infrastructure equipment systems. The essential elements or qualities for a good grounding and bonding system are primarily that it has a low impedance, and secondarily that it be dependable throughout the lifetime of the critical facility. This is typically ensured through properly sized grounding and bonding cables, short cable runs without sharp turns, and connections that are resistant to corrosion or loosening over time.

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

1) Personal Safety: From a "safety first" perspective, we certainly want to minimize the development of any electrical potential that could create a shock hazard to personnel, within and between metallic frames and structures.

2) Equipment Protection: It is critical, and therefore required, that adequate fault current paths be provided so any installed overcurrent devices can disconnect faulted circuits to reduce the possibility of fire and limit damage to the critical equipment. System design and operational procedures for electrostatic protection of equipment is also required.

3) Equipment Operation: Proper grounding provides an equalized ground reference to electronic communication circuits connected to the ground plane.

4) Electrical Noise Reduction: Proper bonding assists in the reduction of electrical interference by maintaining low impedance paths between ground points throughout the communication system.

5) Reliability: Naturally, to protect our investment, we should install a grounding system that resists deterioration, requires minimal maintenance, and ensures network service continuity.

Cable operators must of course meet the basic requirements of applicable national and local electrical and safety codes, and comply with any additional requirements set forth by the local authority having jurisdiction (AHJ).

Telecommunications services providers - including cable operators - recognize that these minimum requirements are often not stringent enough to fulfill the industry-specific protection needs of their modern critical facilities, and so go far beyond the minimum requirements as needed to meet the principal objectives and assure business continuity.

4. Exterior Grounding

Although unwanted electrical disturbances may come from both internal and external sources, the most egregious events come from outside the critical facility. Primarily for that reason, and to provide a commonsense flow to the outline and description of the various elements of a grounding and bonding system, the ANSI/SCTE 275 standard is organized from an "outside-to-inside" perspective. This paper will address the important aspects of grounding and bonding in the ANSI/SCTE 275 in the same fashion.

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, ensuring network continuity through any of these events. 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.

Any ground system installation, whether commercial, industrial, or residential, requires a certain target resistance-to-earth value be met. The industry standards vary on acceptable and maximum values, and environmental or geographic conditions will affect the application of some of these grounding systems. In general, the lower resistance the better, and the target for cable operators is typically 5 Ohms or less, and 25 Ohms would be considered a maximum level.

4.1. Soil Resistivity

The first task in the design of a good ground system is to test the resistivity of the soil surrounding the critical facility. The ground system design and associated components can only be determined after we know what we have to work with. For the soil resistivity, as is the case for the ground system resistance, a lower value is better.

The resistivity (typically measured in Ohm-m) of a soil depends largely on the types of materials that are contained in the soil, as would be the case for metals and any other materials commonly considered conductive. Soils can contain various materials including clays, sands, rocks, shale, etc. It is this combination of materials that largely determines how conductive the soil will be to electric current flow. In addition, the resistivity of a specific type of soil will vary seasonally because of its moisture, temperature and chemical content:

- The greater the moisture content, the lower the resistivity.
- The higher the temperature, the lower the resistivity.
- The greater the salt content, the lower the resistivity.

Though there are several acceptable methods for measuring soil resistivity, the one most commonly used is the 4-point method. In this method, four small-sized (typically 18-inch) electrodes are driven into the earth at the same depth, in a straight line and equidistant from each other. A known current from a constant current generator is passed between the outer electrodes. The voltage drop, which is a function of the resistance, is then measured across the two inner electrodes. Greater detail on the application of best practices for measuring soil resistivity are described in the latest IEEE Standard 81, "Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System".

4.2. The Ground Ring

Once the soil resistivity has been measured, the external ground system can be designed to the specific resistance-to-earth target value. This is accomplished mainly by the ground ring and driven rod electrodes, and depending on the characteristics and limitations of the surrounding earth, may include flat plates, rebar, Ground Enhancement Material (GEM) or chemical ground rods, which are typically hollow copper rods filled with an electrolytic salt mixture.

ANSI/SCTE 275 spells out the best practices and minimum standards for cable operators to go by in specifying an external ground system. The ground ring is typically a 2/0 AWG (minimum #2 AWG) copper conductor buried 30 inches below grade or below the frost line, whichever is greater. The ground rods should be ¾ inch x 10 ft long, buried to the same depth as the ring, spaced 20 feet apart, and exothermically welded to the ground ring. Additionally, there should be several inspection wells or hand holes at key locations around the ring.

The external ground system is typically best designed by engineering companies that specialize in this, and there are quite a few good software programs that are utilized for this purpose; however most electrical engineering firms should be capable of designing an adequate ground system.

Finally, ANSI/SCTE 275 gives direction for the proper grounding of exterior objects like towers, guy wires, satellite dishes, masts, fencing and other metallic objects, all of which should be tied to the external ground ring.

Figure 1 – Exterior Ground Ring Conductor Exothermically Welded To A Ground Rod

5. Interior Grounding

The interior grounding system is the most complex portion of a critical facility grounding and bonding system. It also has the most variations in application between the cable operators, and between the site types (i.e. headend, data center, edge hub site), not to mention the variances introduced by legacy and acquisition sites. While there are good established references there was no detail specific to this industry that could be seen as a standard prior to ANSI/SCTE 275 being released.

Still it was possible to detail minimum standards as well as recommended targets for best practices, knowing that cable operators must weigh costs to upgrade against benefits received. For example, if a legacy site has a #2 AWG ground conductor running along the rows of racks (known as an aisle feeder), and the company specification calls for a 2/0 AWG aisle feeder (the size difference between #2 and 2/0 is not insignificant, but neither is it a 'show-stopper'; it is a commonly used size – especially in legacy sites, and is acceptable as a minimum size in ANSI/SCTE 275), it may be better to wait until an equipment refresh or new racks are installed to do the upgrade, whereas if there is no aisle feeder at all, it should be rectified more immediately.

5.1. Various Grounding System Methods/Theories/Approaches

Most of us have heard the anecdote involving "ask three experts, and you'll get four opinions". In the world of grounding, it is no different. Grounding and bonding - is it art, is it science, is it both? The answer is "Yes".

When you walk into any cable operator headend, telecommunications carrier central office, commercial or military grade data center or critical facility, you will find a variety of grounding methods, and a mixture of some in the same facility, on purpose or by accident, and there are benefits and drawbacks to each.

The main types are Star and Mesh bonding networks, which may or may not be Isolated. What we are mainly talking about is the bonding of equipment racks to the interior grounding system, which ultimately ties to the Master Ground Bar (MGB). Here is an easy way (I hope) to understand it:

- Star means each item (network equipment rack or cabinet) is independently grounded to a dedicated Frame Ground Bar (FGB) which taps into a conductor that goes to a single "point", typically an area ground bar. Most cable and telecom critical facilities use this method, primarily, but not exclusively.

- Mesh means multiple items are bonded to each other in a sort of "grid" fashion. This is typically done in a raised floor data center.

- By Isolated we really mean a "single-point ground" connection to a ground bar, or perhaps to a specific section of a ground bar is involved. A Mesh or Star sub-"area" may have a connection of this type.

These types may be mixed together in a critical facility, the proper use of which may be dictated by the specific grounding needs of the types of equipment, whether they are AC or DC powered, whether they have the chassis bonded or isolated from the neutral or grounded conductor, etc.

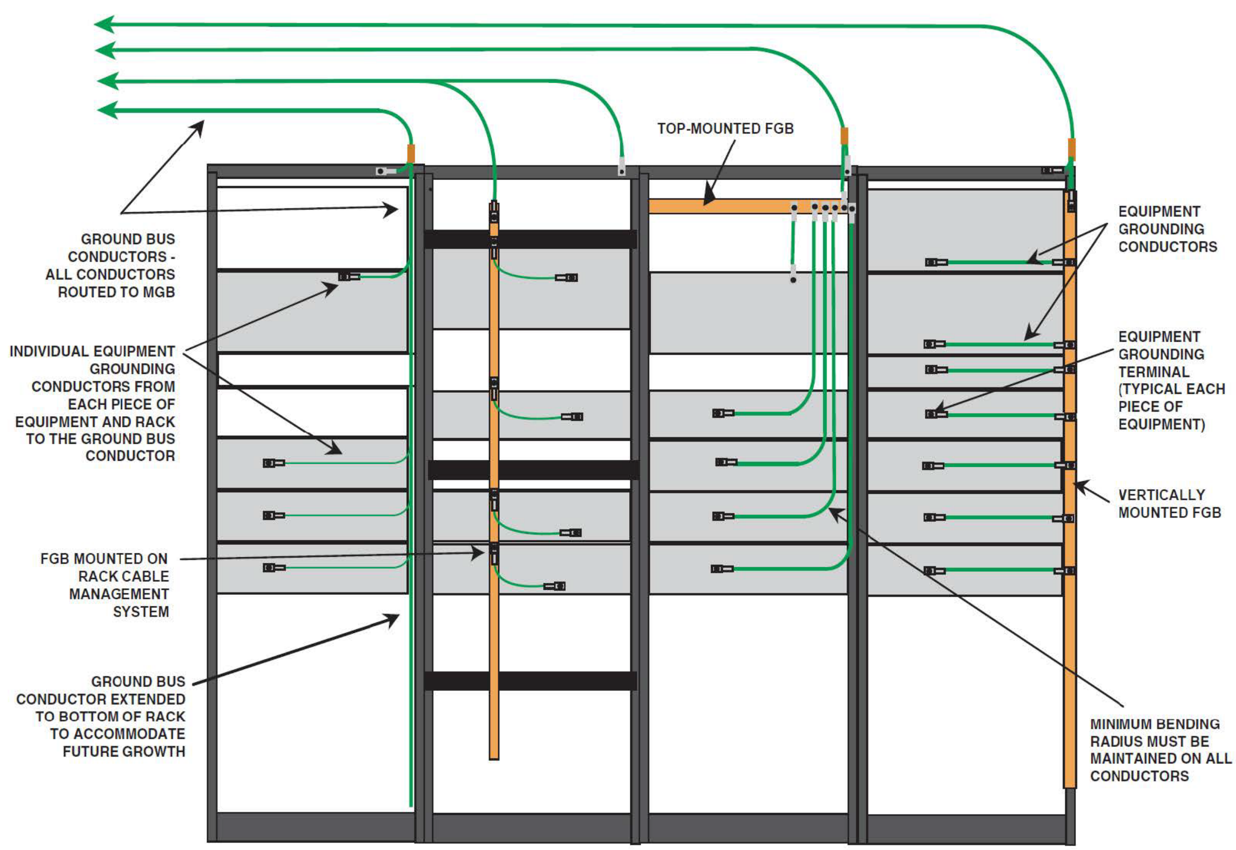

Figure 2 – Acceptable Interior Grounding Methods - Network Equipment Racks

5.2. Common Grounding And Bonding System Requirements

The ANSI/SCTE 275 goes into great detail about best practices of interior grounding and bonding to racks and cabinets, exterior cable entry points, the utility service entrance connection, DC plants and batteries, and multi-floor building applications.

Regardless of the application within the building, there are a few practices that are required for nearly all of them wherever possible:

- Each grounding or bonding connection should be dedicated if possible; no "daisy-chained" or back-to-back connections are permitted in a critical facility.
- Mechanical connections are not permitted to be used for grounding or bonding in a critical facility. All connections should be made using crimp lug or tap connectors.
- Connection of dissimilar metals is prohibited in critical facilities.
- Two-hole lugs should be used wherever possible to prevent rotation and loosening of the lug during or after installation. For some small ground bars within racks or for equipment chassis that provide only a single-hole lug connection, serrated washers should be used.
- Any paint should be scraped off surfaces and anti-oxidation grease should be used for all grounding and bonding connections.
- Ground cables shall "gracefully" flow in the direction of the MGB, as though downstream, with no sharp bends.
- Ground cables of all sizes shall have a minimum bending radius of 8 inches, and the angle of any bend shall not be less than 90 degrees.
- All ground cables that terminate to a ground bar shall be appropriately labeled at both ends.
- Grounding conductors shall be sized per National Electrical Code (NEC) table 250.122

5.3. The Master Ground Bar

The MGB is the primary element of the critical facility grounding and bonding system - it is the single point connection, or main common interface between all interior and most exterior grounding systems of the critical facility. It will typically have connections to the utility ground, the ground ring (two connections, if possible), building steel, cold water pipe, all building interior network equipment area auxiliary ground bars, the DC plant positive return bus, DC equipment frame ground bar, and finally, any cable entry ground bars.

It is very important for all of the conductors that are terminated to the MGB to be labeled. This is helpful for both administrative documentation, maintenance, and troubleshooting purposes when any ground anomalies are discovered.

Additionally, some cable operators employ what is called a PANI configuration of the conductors terminated to the MGB, in order to arrange them according to surge potentials by specific classifications of the grounding system elements. Each section of the MGB is labeled accordingly, and the PANI classifications are as follows:

> **P** - Surge Producers: Typically conductors coming from Cable Entrance Ground Bars (CEGB), as well as generator, UPS, and transformer enclosures

A - <u>Surge Absorbers</u>: Typically contains connections to building steel, the exterior ground ring, the cold water pipe, and the incoming main AC service ground bar – also called the multi-grounded neutral bond

N - <u>Non-Isolated</u> ground zone equipment grounds: Typically includes Secondary Ground Bars (SGB) which are for equipment room ground conductors that include the cabinet/rack grounds, ladder rack, etc.

I - <u>Isolated</u> ground zone equipment grounds: Typically equipment associated with a digital telephony switch, logic grounds and the DC Plant reference ground

Finally, proper connections and cable sizing of the conductors terminated to the MGB help to achieve network reliability by increasing the resilience of the grounding system to ensure it will protect the operational integrity of the equipment and infrastructure within the critical facility.

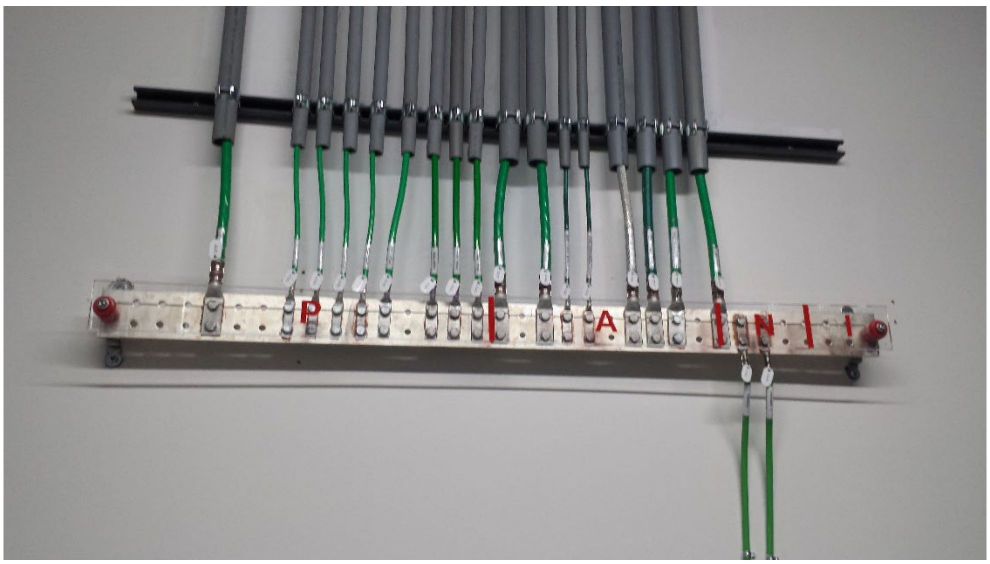

Figure 3 – Master Ground Bar With PANI Configuration

6. Surge And Lightning Protection

Surge and lightning protection systems complement each other and represent the most efficient and cost effective way to ensure continuity of the network by preventing or mitigating any deleterious effects from voltage instability and high frequency electromagnetic disturbances which are known to cause the most damage to network equipment and infrastructure.

Lightning strikes and electric utility company switching can cause voltage surges on the incoming AC power feeders. To protect the critical facility from these voltage surges, a surge-protective device (SPD) meeting current UL standards 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. Additional SPDs may need to be installed on downstream AC panels as required by special circumstances for a specific facility, such as those located in areas with high lightning activity or unstable utility power. Care should be taken when specifying these additional devices to ensure they are properly coordinated with the upstream SPDs according to their permissible energy.

A roof mounted lightning protection system is designed to protect a facility by intercepting lightning flashes and conducting the lightning currents into the earth in a safe and efficient manner. A properly designed lightning protection system should protect the facility from structural damage that can be caused when lightning currents flow through a building's concrete and metallic superstructure. The roof mounted lightning protection system should connect to the facility buried ground ring through down lead conductors spaced in accordance with NFPA 780, "Standard for the Installation of Lightning Protection Systems".

A lightning protection system consists of air terminals, conductors, interconnecting conductors, down leads and all the fittings, brackets and support devices required to complete the system. The final installation should be inspected, and UL certified to indicate that it has been properly installed and is compliant to all national and local standards. All down leads should be tested to verify that they are making a low impedance connection with the buried ground ring.

7. Humidity And Electrostatic Discharge

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 electrostatic 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.

Some of the best practices detailed in ANSI/SCTE 275 are as follows:

- To avoid damage of electrostatic dissipative (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 and anti-static bags should be used by all personnel handling printed circuit boards and blade server type cards.
- There should be wrist strap test stations at all critical facility sites, and wherever sensitive electronic components are handled.
- ESD-rated grounded conductive floor tiles or mats should be installed near the base of each equipment rack.

By employing these best practices, cable operators will be better able to achieve reliability targets and ensure network continuity.

8. Commissioning And Maintenance

The commissioning of a critical 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, and help to ensure network resilience and thus meet reliability KPIs.

Commissioning entails the visual inspection of the interior and exterior grounding systems, lightning protection system, and SPD installations to verify that the electrical contractor has built these systems in accordance with the design engineer's drawings and specifications, as well as compliance to all applicable standards.

In addition, current measurements are made in all conductor connections to the MGB to identify any unwanted ground current loops in the system, and impedance measurements are made in the lightning protection down leads to verify they are connected to the buried ground ring.

Grounding system preventive maintenance is required periodically, to protect equipment and facility investments, as well as to ensure continuity of network resilience. Improper grounding and bonding, combined with the inevitability of internal and external power surges are the most likely reasons for network equipment failures from "unknown causes" and are often incorrectly attributed to equipment defects.

Replaced equipment will likely fail repeatedly unless the root cause is determined. Ongoing maintenance of the grounding and bonding systems helps to identify the potential causes for ground and surge protection issues before they happen.

9. Conclusion

As we are all aware, these are unusual times, and regardless of the political, environmental or biological climate that cable operators find themselves having to navigate and make adjustments for, there are certain non-negotiable elements of doing business in an uncertain world. The business bottom line is primary of course, and second to that is the customer, without which there is no bottom line.

The cable operator customer of the third decade of this millennium expects a reliable network, and continuous, seamless delivery of services, whether it be broadband cable, internet, telephony, cellular, wireless, home security, telemedicine, etc.

One primary way that network resilience can be attained, risk to service delivery continuity mitigated, and reliability targets realized is to invest the time and energy and dollars to deploy and maintain a solid grounding and bonding network, and the ANSI/SCTE 275 standard is the best way to achieve that objective.

Abbreviations

AC	alternating current
AHJ	authority having jurisdiction
ANSI	American National Standards Institute
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
AWG	American wire gauge
CEGB	Cable Entry Ground Bar
DC	direct current
ESD	electrostatic dissipative
FGB	frame ground bar
GEM	ground enhancement material
IEEE	Institute of Electrical and Electronics Engineers
KPI	key performance indicator

MGB	master ground bar
MSS	main service switchboard
NEC	National Electrical Code
NFPA	National Fire Protection Association
Ohm-m	Ohm-meters
RH	relative humidity
SCTE	Society of Cable Telecommunications Engineers
SGB	secondary ground bar
SPD	surge protective device
UL	Underwriters Laboratories

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