The Case for Improved Electrical Grounding Standards In An Electronics-Driven Society

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INTRODUCTION

Globally, the use of ground rods, grids, and metallic plates in a variety of forms has been the recognized standard for electrical grounding and earthing for well over 85 years. Beginning in 1936, these techniques have been, and continue to be specified by multiple engineering, building, industry-specific, and national code publications. Furthermore, contemporary surveys of patent applications and granted patent documentation in the United States for the past decade indicate that the universal acceptance of these methods remains in place for electrical grounding and earthing. This is despite rapidly increasing evidence of severe shortcomings of such grounding equipment in protecting critical assets from lightning and large electrical transient events.

Of present interest is the protection of *electronic* devices. Now ubiquitous, electronic circuitry literally runs our world. Regardless, damage and losses of these assets are increasing at unacceptable levels not because of more thunderstorms or electrical surges, but instead due to fundamental failures of now out-of-date electrical protective strategies which have been essentially unchanged for many decades.

This condition should be seen as a “red flag” event, yet no significant improvements to grounding and earthing – the most effective way to protect electronics – have been proposed in nearly 50 years: The same concepts that were used in the 1970s *prior to the electronics revolution* are still in universal use today.

This situation is graphically and clearly depicted in Figure 1. The orange shaded section of the drawing indicates the rough timeframe where electronic and solid-state circuitry began to replace electric, electro-mechanical, and true analog equipment. Additionally, simultaneously, the cost and complexity of these devices began to increase noticeably. (As an analogy, think of the options and features available on a 1980s automobile, and those available now.)

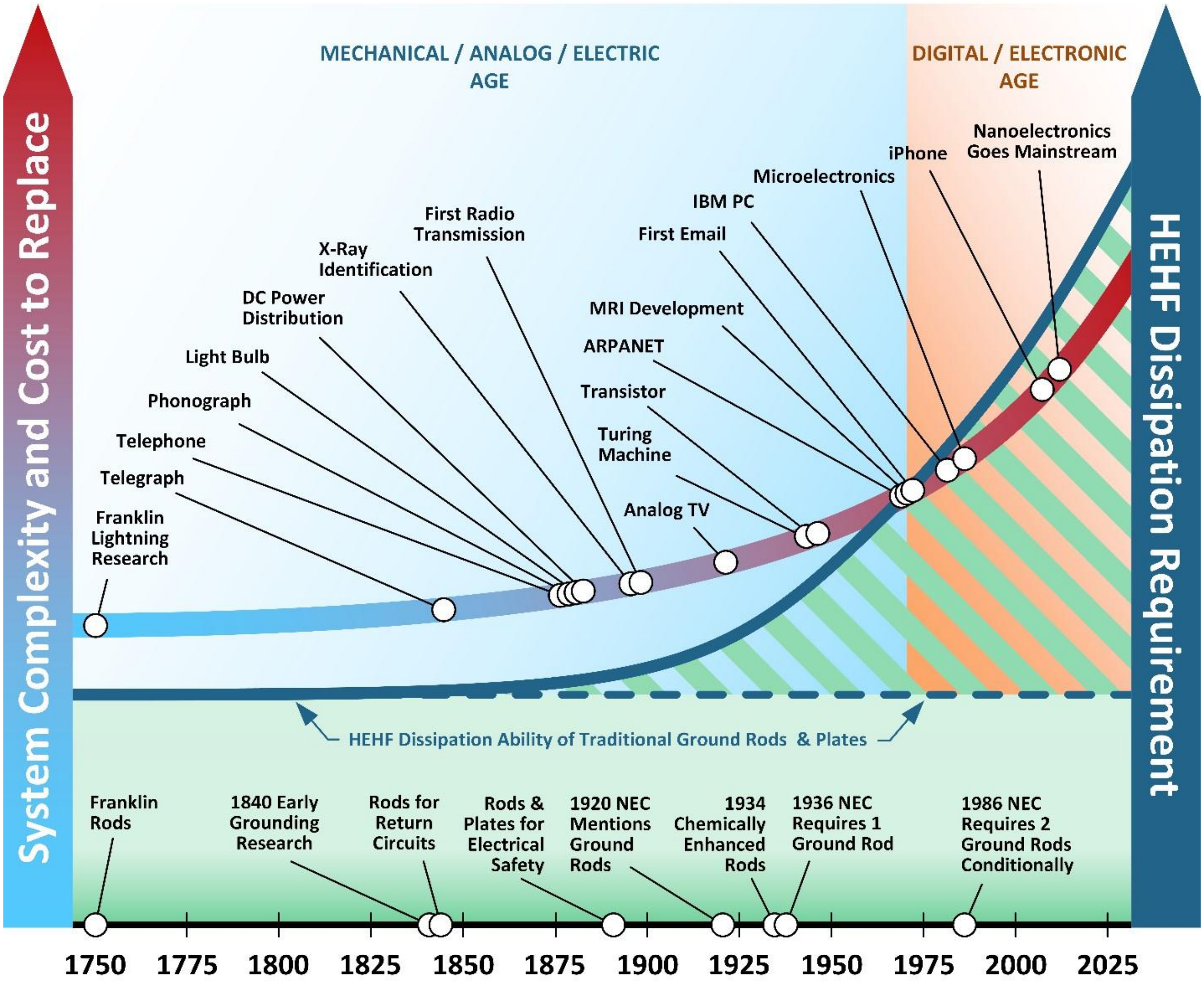

Figure 1: HEHF dissipation requirements and capability of ground rods compared with device complexity and cost.

With the switch to electronic circuitry, the sensitivity of these devices to the quality of power supplied began to increase. This, in turn, should have resulted in better abilities of removal and dissipation of significant electrical anomalies through improved grounding techniques. Unfortunately, this improvement never happened. The green shaded area of Figure 1 represents that the ability to manage high-energy / high frequency[1] (henceforth: “HEHF”) faults on power supply has not changed – because traditional grounding techniques have not changed commensurate with the technological changes of the last 50 years. The green diagonal lines under the dark blue “HEHF” curve indicates the “dissipation requirement gap” between legacy grounding and that necessary for protection of contemporary (now nano-scale) electronics from lightning and other HEHF events.

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[1] In this context, HEHF includes a broad range of frequencies well beyond 50/60 Hz.

The practical result is the electronic devices on which we now rely so heavily, when exposed to what are commonly referred to as "power surges" are tremendously more sensitive to electrical anomalies than the appliances, transmitters, or entertainment devices of the past. The intent of this paper, therefore, is to draw much needed attention to present grounding and earthing strategies, particularly with respect to the nature of our electrical system and the highly sensitive loads it powers.

In the following material, we posit that:

1) Virtually all codes and standards, whether local, national, international, or industry specific, are seriously out of date with respect to lightning and lightning related transient currents. They are not wrong, just dated – given the discoveries of the last three decades.

2) Present strategies are ineffective for management of HEHF surges, and

3) Grounding systems presently installed need to be augmented to prevent HEHF damage to electronics, and with urgency in mission-critical applications.

In this paper we explore the reasoning behind these positions, discussing the now known limitations of "traditional" or "legacy" grounding with respect to the electronic devices that power our world.

Most importantly, we highlight the essential difference between simply getting a transient or fault current ***to*** ground as opposed to getting the same charges ***into*** the ground. The importance of this distinction cannot be understated: Across the Globe, society has reached the point where all the basic underpinnings of our social, productive, and governmental infrastructure are increasingly at risk due to our failure to prevent damage to the electronic hearts of these systems. The case for rethinking electrical grounding techniques, especially with respect to protection of essential electronic equipment, has never been stronger.

BACKGROUND

During the first quarter of the 21st Century, the takeover of most every aspect of society by electronic devices has been pronounced and comprehensive — from communications to household automation, energy distribution to infrastructure management, and everything in between. Massive improvements in productivity and a wide range of social efficiencies have been the result of this transformation.

Notably, because of these great benefits, society has now become reliant, if not dependent, on electronic devices to run our lives. As such, the criticality of ensuring constant availability of electronic technologies has never been greater. Despite this situation, the methods we use to protect our ultra-sensitive, often mission-critical electronic devices from damaging electrical anomalies are verifiably no longer sufficient. Such traditional grounding and earthing strategies may in fact now be considered obsolete and insufficient with respect to electronic assets.

At the heart of electronic innovation is the ability to reduce the size of circuitry to nanoscale levels and concurrently increase the speed of the processes accomplished by such circuitry Circuit *density*, thus, becomes extremely high — to the point where mere *millivolts* of stray potential in the wrong place can cause destructive currents to flow making the device controlled by the damaged circuity completely inoperable.

Therefore, prevention of the exposure of micro and nano-circuitry to even the tiniest of electrical anomalies is essential.

And therein lies the rub with respect to traditional electrical grounding techniques: These methods were conceived over 90 years ago primarily for the purposes of structure (fire) protection, utility personnel safety, ground plane creation for AM radio broadcasting, and the balancing of electrical distribution networks. *Importantly, for these purposes, they have worked very well.*

However, at the time traditional grounding techniques were developed, electronic devices – and their extreme sensitivity to power supply anomalies – **did not exist.** But now, despite reported global annual losses of billions of dollars (and other currencies) in electronic equipment incurred due to lightning strikes, uncontrolled transients, and other electrical anomalies, national and international codes and standards continue to require the use of near century-old technology in the form of common ground rods, grids, and plates for all earthing applications worldwide. Unfortunately, these losses are continually increasing as the constant and expanding interface of electronics in our daily lives falls prey to electrical anomalies — *and does so without the benefit of truly protective grounding*.

RECENT RESEARCH AND DISCOVERY

- Lightning

That grounding methods and practices have not kept pace with electronic protection requirements from lightning is quite surprising because research on the characteristics of lightning and lightning-related electrical anomalies has been extensive over the last 30 years. While a variety of mysteries remain, a great amount of valuable information about lightning has been developed in this span of time.

Notably, lightning is now known to be much more than a simple DC event as was believed for many years. While accumulated positive and negative electromagnetic fields can explain a wide range of lightning characteristics, some critical aspects of the behavior of lightning do not follow this model. Of these, the amazingly fast rise time in energy of a lightning discharge establishes the existence of very high frequencies at the initiation of the event. Critically, traditional grounding and earthing codes and standards generally[2] overlook high frequency characteristics in lightning and make no provision for preventing damage from these pulses.

This unrestrained freight train of electric current and potential - reaching peak energy in less than 10µS[3,4].... ten *millionths* of a second … may hold more than 250,000 volts, and well over 30,000 amps of current -- and is composed of a cacophony of frequencies up to at least 300MHz! [5,6]

Because traditional grounding was not developed with these intensities and frequencies in mind, it should be no surprise that these "legacy" grounding devices are in far too many cases simply overrun and/or swamped by lightning and lightning-related electrical events. This results – also too often – in catastrophic failure of what were thought to be protected assets.

- Impedance Mismatch

Impedance mismatch is a condition which exists everywhere between a grounding electrode of any type and native or amended surrounding soil, and results from the resistance of the electrode being dramatically lower than that of the surrounding soil.

In this situation, traditional grounding devices will *reflect* some of the electrical charge entering a grounding system instead of dissipating it into soil. This results in a backwards flow of high energy current, u*pstream – into* the very equipment the grounding system was installed to protect. In a bit more detail, impedance mismatch limits the ability of traditional grounding to manage massive current surges and spikes, leading to reflection. Stated simply, the impedance of copper in the form of a rod, plate, or cable is always tremendously lower than surrounding soils and, to a lesser degree, lower than chemically

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[2] IEC 62305 "Protection Against Lightning" and IEC 62561-1 "Lightning Protection System Components (LPSC)" both refer to high frequencies needing to be considered but only for lightning though it would seem that this limited consideration has not made it into the field.

[3] Rakov, V., 'Characterization of lighting electromagnetic fields and their modeling', *The International Conference on Electrical Engineering*, 6(6th International Conference on Electrical Engineering ICEENG 2008), pp. 1-31. doi: 10.21608/iceeng.2008.34378

[4] Romero, Carlos, *et. al.*, "A statistical analysis on the risetime of lightning current pulses in negative upward flashes measured at Säntis tower," 2012 International Conference on Lightning Protection (ICLP), 2-7 Sept. 2012.

[5] Chen, M. *et al.*, "The Electromagnetic Radiation from Lightning in the Interval of 10 KHz to 100 MHz," 2003, Environmental Science, Physics, DOI:10.1007/BF01042441

[6] Vine, D., "Review of measurements of the RF spectrum of radiation from lightning," 1987, Physics, Environmental Science, Meteorology and Atmospheric Physics.

modified soils. A variety of research has shown the impedance of copper to be as much as one *billion* to one *trillion* times lower than native soils – anywhere in the world. As such, getting a transient charge to leave its highly conductive copper "home" and jump into *relatively* very resistive soil and dissipate - *which is the goal of all grounding and earthing* - is more challenging than common wisdom suggests. This is especially significant during the huge inrush of energy at the initiation of an anomalous event. Substantial research on this latter condition exists and has been broadly supported.

Traditional grounding systems, whether rod, plate, or grid based, are not required to have a surrounding additive or conditioning soil[7] and hence may not address impedance mismatch issues at all. However, many common commercial grounding systems do specify a variety of soil amendments[8] as an option to theoretically improve dissipation into native soil. A significant number of these additives are cement-based but contain either carbon fiber "dust" or more corrosive "coke breeze", a fine powder of coked coal. These additives are a step in the right direction, but they also have substantial limitations, not the least of which is the continued use of a smooth copper conductor interfacing with the slightly conductively enhanced cement-based additive. Importantly, this is not an ideal combination for dissipation of high frequency current. On the other hand, low frequency pulses can be managed somewhat better by this arrangement, but by the time these lower frequency flows arrive (generally greater than 10µS into the event), the HEHF punch at the initiation of the event may have already been rejected by the grounding electrode, reflected out of the grounding system, and moved in for the kill on connected sensitive electronics.

- TO the ground versus INTO the ground

As stated at the beginning of this paper, the distinction of *TO* the ground as opposed to *INTO* the ground cannot be emphasized enough. High frequencies now known to be present in a lightning or lightning related event, as well as occasionally in other transient events, expose substantial limitations in traditional grounding -- which was primarily designed for dissipation of lower frequency (50-60Hz) current. Notably, these legacy strategies often fail to sufficiently dissipate charges exceeding 100MHz. Thus, the standards and codes that specify grounding schemes which only convey surge and spike current TO the Earth *without achieving full dissipation INTO the Earth* are leaving essential assets exposed to damage and destruction.

Damage to electronics of any type from grounding system reflections is exacerbated by established codes and standards that specify the common bonding of a traditional grounding system with a combination of grounding leads for structure protection, a building's electrical system, and essential electronic devices inside the building. A grounding strategy of this type does indeed create equipotential in site grounding, but it

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[7] These are generally referred to as ground improvement materials (GIMs) or ground enhancement materials (GEM) which may be divided into multiple separate mixes as taught in US11329406B2 (LaBarge *et al*.) [8] Azmi, A., *et al.*, Indonesian J Elec Eng & Comp Sci; Vol. 13, No. 2, February 2019, pp. 453~460 ISSN: 25024752, DOI: 10.11591/ijeecs.v13.i2.pp453-460.

also *ensures* that if any *rejection* of fault current due to impedance mismatch or swamping occurs, electronic equipment that was presumed to be protected will instead be directly in the line of fire.

This so-called “single point grounding” approach assumes that any intensity or frequency of fault current will be completely absorbed and dissipated by a bonded grounding device. Unfortunately, empirical evidence shows that this is often not the case.[8,9]. When reflection or rejection of charge occurs because of traditional grounding limitations, anything bonded to the grounding system quickly becomes a target of undissipated energy.

As an example, assume a broadcast tower is bonded to a traditional site grounding system that is also directly bonded to the equipment racks inside the transmitter shelter via a common bus bar. If a nearby lightning strike energizes the tower with a high frequency pulse that is rejected by the ground rods of the local earthing system (due to impedance mismatch or the frequency limitations of copper conductor dissipation), the undissipated energy has a clear path into the transmitter shelter *on grounding conductors* and directly into sensitive electronic equipment. Damage to or destruction of important assets can and does easily result.

Similarly, when electric power supply lines are over-energized by nearby lightning events, transient current will flow on phase *and* Neutral lines throughout the immediate network. Pole-sited ground rods (connected with light gauge wire – AWG #6 – and very often with excessively high resistance-to-ground levels) will tend to reject this spike or surge. The transient then continues to move ultimately toward customer locations where, again, *standards-required* meter base traditional rods, plates, or grids reject the charge. If this over-current event reaches the site grounding network, virtually everything connected to that network is now fair game. Electronics are the first to go….
nearly every time.

Amazingly, in field analyses of many dozens of electronics-related grounding systems, we have found the source of damaging currents by more than a 2-to-1 ratio is the inbound commercial electric service, NOT lightning strikes on structures (such as broadcast towers)

- Surge Suppression Limitations

Reliance on surge suppressors for lightning protection of electronics is not a panacea as often portrayed. These devices *depend on* traditional grounding methods to dispose of intercepted faults. At the heart of most suppressors are Metal-Oxide-Varistors (or MOVs).

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[8] Rakov, V., 'Characterization of lighting electromagnetic fields and their modeling', The International Conference on Electrical Engineering, 6(6th International Conference on Electrical Engineering ICEENG 2008), pp. 1-31. doi: 10.21608/iceeng.2008.34378.

[9] Baba, Y and Rakov, V.A., “On the interpretation of ground reflections observed in small-scale experiments simulating lightning strikes to towers”, IEEE Trans. on EMC, vol. 47, no. 3, pp. 533-542, Aug. 2005.

When coupled with standard legacy grounding techniques, introduction of an HEHF event to a MOV will far too often yield insufficient attenuation of the event thanks to 1) The inability of the MOV to “see” an appropriately “easy” path for elimination of the undesirable current, and 2) The use of suppressors _only_ for attenuation of phase (or “hot”) line transients and faults. Neutral lines are generally not part of a suppression scheme.

In the first situation, if current entering a surge suppressor circuit does not have an extremely low impedance route to *dissipation*, output from the MOV can be severely constrained thus yielding a failure to remove all the undesired characteristics of a transient event. Damage to downstream equipment, *as well as the suppressors themselves*, is probable. As already discussed, when transients and faults have large HEHF components, the limitations of traditional grounding which cause reflection of a fault out of a grounding device -- instead of dissipation -- likely will create conditions where surge suppression is ineffective for protection of electronic devices.

The second condition above has a wider variety of implications. To assist, a graphic representation of a simplified electric power supply arrangement is shown in Figure 2.

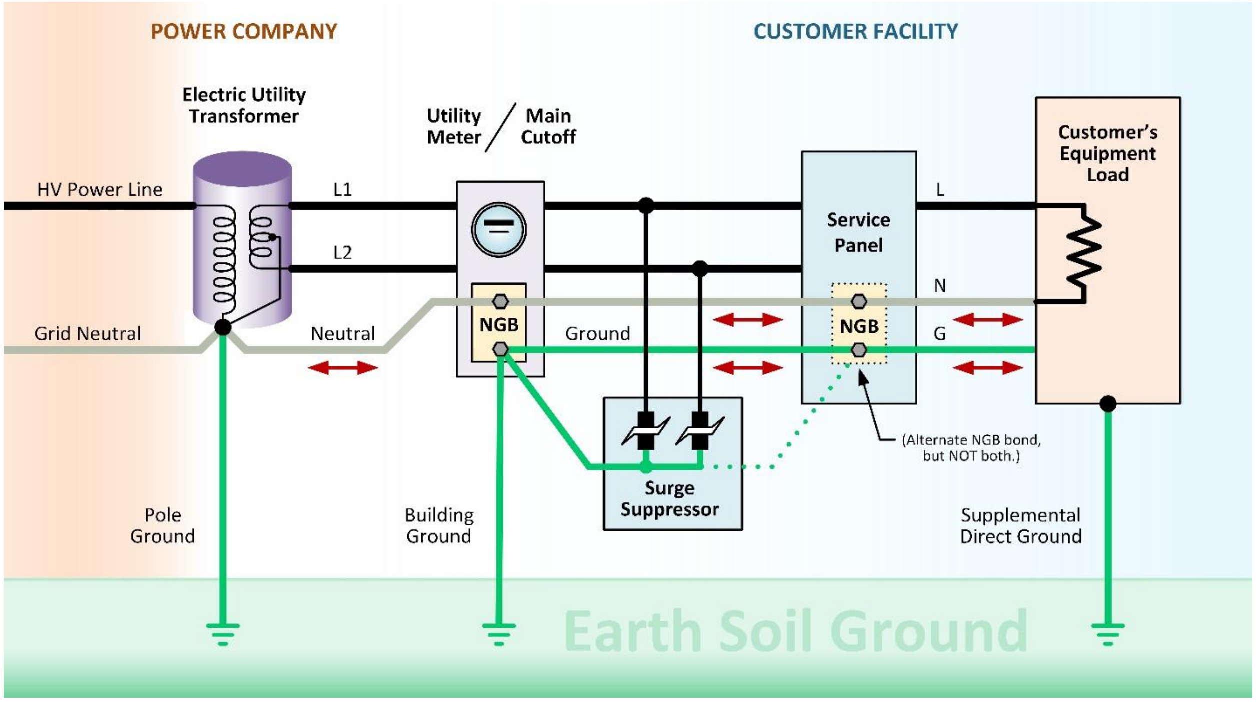

Figure 2: Simplified representation of typical U.S. electric power supply system.

Inbound phase lines of the desired voltage (shown as solid black lines) originate at a transformer and run to a meter base and service entry, then either to a main cutoff point or a circuit distribution panel. (The meter base may also be the main cutoff point.) At some location between the meter base and the panel, a surge suppressor often is attached as a “stub” circuit. Here, phase lines are routed into MOV suppressor modules which are designed to prevent undesirable currents and voltages from passing into the facility electric system. The theory is that at this point, excess energy will sense a speedy route to ground via the clever design of an MOV and flow to a traditional grounding device outside the facility instead of into important equipment.

In Figure 2, this “escape route” is shown as a ground (green) line running from the surge suppressor to a Neutral-ground bus (“NGB”) in either the meter base / main cutoff, **or** in the circuit distribution panel. (Configurations vary depending on electrical code and/or facility requirements.) From here, the over-voltage event, in theory, will flow to a traditional grounding device and be dissipated away.

As was just mentioned, traditional grounding doesn’t always have the capability available for faults on phase lines entering surge suppressors. Importantly, the same holds true for Neutral lines in a power supply system: The Neutral can just as easily convey high energy fault and transient current into a facility as phase lines. Under the right circumstance, HEHF events can flow both into and away from an important facility. But more critically, the Neutral line is rarely, if ever, connected to surge suppression. Combining these factors, it becomes quickly clear that traditional grounding no longer provides sufficient protection from HEHF anomalies on Neutral lines. Nevertheless, facility design engineers continue to assume that a code-required ground rod or other standard grounding device at the entry point of a power supply (such as the meter base or main cutoff device in Figure 2) will always be able to intercept *any* undesirable inbound Neutral current flow. Field evidence to the contrary is overwhelming.

As such, an HEHF event on Neutral is a perfect storm for damage likelihood: Little protection is offered by traditional grounding at service entry, and surge suppression is not part of the protection scheme. Therefore, fault current on Neutral essentially has free rein on infecting sensitive equipment once it passes the service entry grounding device(s). Even surge suppressors can be terminally damaged by Neutral faults that bypass standard grounding because substantial energy, flowing backward into a suppressor, can wreak havoc on such devices, but more likely on other downstream equipment via phase-carrying lines connected to suppression devices.

Interestingly, most of the major codes and standards for grounding are almost entirely silent on ensuring Neutral lines have extremely robust charge dissipation available to them. Apparently, the operative assumption is high energy Neutral line current *always* flows away from the loads within an electrical system – and toward either traditional grounding or the nearest power substation. This is a clear oversight as electrons *will* flow entirely according to voltage and resistance at a given instant. The 250,000 volts of a typical lightning bolt in the immediate proximity of an aerial Neutral line will overrule most any opposing current flowing from a service load.

Without suppression or dissipation via traditional grounding available, HEHF events on Neutral are highly likely to inflict damage on electronic equipment. Without improved broadband grounding standards, non-suppressed, insufficiently grounded Neutral lines will continue to be a source of dangerous transient current flows.

Finally, although sacrificing surge suppressors is indeed less expensive than destroying other more valuable equipment, once a suppressor is compromised, any downstream equipment is fully exposed to damaging surges until the suppressor is replaced. In locations where lightning and line surges are frequent, it is imprudent to leave mission critical equipment unprotected for even a brief span of time.

Generally speaking, with respect to surge suppressor strategies, if a transient event (especially an HEHF fault) has bypassed every traditional grounding "opportunity" on inbound electric service all the way up to the serving transformer for a given location, expecting traditional grounding beyond this point, in combination with surge suppression, to fully manage all aspects of phase and Neutral line transients may be overly optimistic. The serious limitations of this fully accepted approach to damage prevention are clear.

- Service Entry Grounding: A Significantly Overlooked Issue

The National Electric Code (the NEC) requires at least one ground rod (or other approved grounding device) "at the point of first service disconnect" on any electric service delivery point. That's a good recommendation, but in an electronics-dependent world, this traditional technique is by no means sufficient. The reasons for this assertion follow.

  - In addition to the above requirement, the NEC states clearly that when standard ground rods are used, grounding performance must be measured to determine the resistance-to-ground (RTG) of the grounding system. If this measurement is 25 Ohms-to-ground or less, the installation is complete. However, if the measurement exceeds 25 Ohms-to-ground, a second rod must be installed. Importantly, the NEC has *no requirement to measure the performance of a grounding system using more than one ground rod*. Instead, the Code says the installation is complete – without performance measurement upon the installation of the second rod – even if the RTG is many times greater than 25 Ohms-to-ground. In practice, this means electricians and installation personnel simply carry two ground rods for a given job and never attempt to measure performance. Voilà!! Every service entry ground with two ground rods is instantly NEC compliant, *regardless of RTG performance of the installation.* This is a dangerous oversight.

  - Service entry grounding using traditional ground rods, chemically enhanced rods, rebar grids, or grounding plates is subject to all the HEHF limitations already mentioned in this paper. Hence, if HEHF charges are rejected by the grounding system, they will happily continue inside the “protected” structure and likely cause damage to electronic devices. In the case of two rods that have a very poor RTG capability, as discussed in the prior bullet point, this is a near certainty.

- Traditional service entry grounding was designed as a point of grounding for *outbound* fault current initiated by short circuits or other failures *within* the protected structure to prevent dangerous conditions, including fire, for inhabitants. Transient and fault current events are often initiated by lightning well away from the protected structure and will travel *toward* a protected structure on service lines, notably including the Neutral line. This being the case, traditional grounding at the service entry simply is not sufficient to prevent electronic damage due to *inbound* major surges and spikes – nor was it designed to do so.

- As stated elsewhere in this paper, empirical evidence shows that at broadcast sites of any type, whether emergency radio, television, or cellular, lightning damage to system electronics is caused by inbound transient currents – as compared with direct strikes to antenna towers and support structures – by a more than two-to-one ratio. Given the above information on service entry grounding requirements, the reasons for this surprising ratio are easy to see. In addition, the standards set of a variety of other national and industrial codes pay far more attention to the bonding and grounding of towers and internal equipment than to prevention of inbound service anomalies.

- Service entry grounding strategies that allow “piggybacked” combinations of electric service grounding with grounding for telecommunications providers’ networks results frequently in a “force multiplier” effect for electronics damage. The reasoning is simple to understand: When lightning events strike near an aerial wire network carrying communications systems lines like coax cable or copper telephone lines as well as electric distribution lines, electromagnetic fields of substantial force can induce current to flow in all of these lines. Even certain types of strengthened optical fiber lines can carry undesirable currents in their support wire. When communications line grounding is piggybacked on rod-based, traditional electric system grounding (either at a customer location or on electric utility equipment pole grounding lines), the resulting inbound transient surge impact can be multiplied. Without the ability to fully dissipate HEHF events of any source, rejection of the charge is even more likely – and nearby electronics suffer disproportionately.

- Where surge suppressors are used to harness surge currents on inbound Phase lines, far too often the output of intercepted over-voltages grabbed by suppressors is simply routed back to the nearest grounding device which generally is the service entry ground. But as in the above discussion on limitations of surge suppressors, because Neutral lines are bi-directional in severe transient conditions, use of traditional grounding devices for suppressor output is inappropriate for HEHF current. When a standard service entry ground is used for suppressor output, simultaneous transient anomalies on the Neutral line (which feeds directly to the service entry ground) can run head-on into Phase-line faults trying to flow from a suppressor. Sadly, in this case, neither the Phase-line nor Neutral faults will be dissipated. Instead, the suppressor itself as well as all connected electronics are in jeopardy.

- All of the above issues are exacerbated when the protected structure is located at the end of an electric supply line. If transient current has found its way to the end of the line thanks to insufficient upstream pole grounding (which is extremely common), and the only available outlet to ground is less-than-robust service entry grounding, customer electronics in the protected shelter become a “catcher’s mitt” for inbound overvoltage.

Taken together, the shortcomings of present code and practice with respect to service entry grounding are likely dramatically responsible for ever-increasing amounts of damage to expensive and critical electronic infrastructure. The necessity of rethinking the requirements of grounding at service entries (and throughout distribution networks) could not be more evident.

In all of the above situations, and in a wide range of other commonly observed grounding system standards and installations, the assumption that traditional systems can fully dissipate *any and all* inbound fault current or transients -- including HEHF events and especially lightning-related pulses -- *INTO* the Earth is poorly supported: The aforementioned trends in electronic damage around the world due to electrical anomalies are strong evidence of this as condition that must be managed very quickly. At a minimum, augmentation of existing grounding strategies with HEHF-capable earthing devices is clearly indicated.

CONCLUSIONS

What worked well for grounding and earthing in a pre-electronics, “analog” world does not work so well now. The reason is simple: When charge is not fully dissipated into the Earth, it WILL instead find a path of lower resistance to release its energy either as light, radio frequencies (RF), sound, heat, or dispersed current — the latter two of which can easily be lethal to electronics. Insufficient, totally missing, or incorrectly bonded grounding networks simply must be brought to a higher standard if we wish to reduce the exposure to damage faced by the critical electronics that run this world.

The above scenarios clearly establish the need for a fresh look at the techniques used for grounding and earthing. Research on improved grounding should concentrate on achieving *immediate dissipation* ***into*** the Earth of surges and transients of any nature, and across a very large range of frequencies: A broadband approach to grounding and earthing – with complete dissipation as the goal – is now essential.

To start this process, it is absolutely necessary to end the practice of solely concentrating grounding designs on the acquisition and routing of charge simply ***to*** grounding/earthing systems – *especially grounding systems that were not designed to manage HEHF currents.* To this day, published standards and codes for grounding/earthing spell out – over hundreds of pages – the need for extremely reliable bonding of all components of a grounding/earthing system, as well as which equipment must be connected to a grounding system and how. These are all wise recommendations. Concurrently, however, these same codes contend grounding devices that demonstrably do not have the ability to completely dissipate a wide range of electrical anomalies into Earth are entirely suitable for protective grounding in ANY application, for any inflow of energy, whether caused by lightning, load-induced transient, switchgear failure, or any other anomaly.

Given what is now known about lightning and related transients, this simply is not a realistic solution: Traditional grounding and earthing was designed almost exclusively for the purposes of structural safety and the balancing of early, very low frequency electrical systems. Legacy grounding strategies were never concerned with, and hence not built for, dissipation of high energy charges - especially those at high frequency because 1) HEHF events were not considered as a key part of lightning discharges in the past, and 2) Because sensitive electronic devices that are damaged by such events did not exist.

Therefore, to assume that rods and plates are indeed capable of required protection for electronic devices is now easily seen as inaccurate on a constant basis.

Interestingly, coming forward to the present day, despite over two decades of research on the inability of traditional grounding/earthing to dispose of high frequency energy, the most prominent codes and standards for grounding continue to effectively ignore high frequency fault and transient events – the culprits behind destruction of electronics. This major oversight is clearly the cause of perpetually increasing levels of damage to electronics and mission-critical systems across the world.

As such, a full updating of grounding / earthing standards in a way that establishes enforceable rules, not just suggestions, which require engineers, technicians, electricians, and general contractors to create and maintain grounding/earthing systems that are capable of properly dissipating HEHF current flows into Earth, and hence preventing damage to our electronics-driven world, is clearly necessary. Failure to address this critical issue will absolutely ensure the continued loss of extremely valuable, often completely essential assets and systems because of intransigent adherence to now obsoleted standards.