Protecting the Broadcasting Plant: A Critical Look at Accepted Electrical Grounding Techniques

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Abstract - *This paper explores the position that traditional grounding design, as used in the broadcasting business (and nearly all others), has not kept pace with electronic technology in common use today. Furthermore, the methodology used to create traditional grounding is overly assumption-driven, resulting in inaccurate, often fully insufficient or unstable grounding strategies. What has sufficed as suitable grounding in the past, simply doesn't fit well with the sensitivity (and expense) of broadcasting facilities and equipment now deployed. The increasing costs and frequency of losses being incurred by broadcasting operations due to lightning and other electrical-related damage are clear evidence of the shortcomings of traditional ground rod arrays and accepted analytical techniques. Therefore, changing the way grounding solutions are envisioned and applied appears to be imminently necessary.*

At its very core, all output from the broadcasting business is dependent on manipulation of electric current applied by production and transmitting equipment. Although the cameras, processors and amplifiers....along with most everything else used in this business are rather complex, the bottom line simply is -- a broadcast product is completely produced and distributed through creative, communicative use of electricity.

And so, because the process of broadcasting is really only a managed flow of electrons, it stands to reason protecting a broadcast plant, its equipment, and its structures from anomalies that can impact this orderly flow of energy would be very high on the to-do list for broadcast engineers. In fact, as the industry has moved into the fully digital / HD world, throughout the process of acquiring and getting a signal onto the air, the sensitivity of broadcast facilities to electrical system anomalies has increased rather dramatically: Electronic devices with their incredible processing speeds and amazingly dense micro/nano circuitry absolutely require perfectly stable power supplies to function as required. When electric surges or spikes (or worse….”steep wave front” events, such as lightning) find their way to transmitters, studios, and antennae, bad things can happen. Make that, bad *expensive* things.

As has been known for well more than a century, electricity is a flow of energy which is harnessed to perform certain (and innumerable) tasks. To flow – that is for a current to exist – there must be a place for the flow to go, so to speak.

Happily, that *place to go* is rather big. It's called Earth. And, in the US anyway, the process of giving electricity a place to go is called *grounding.* (For the balance of this paper, the more widely used term of “earthing” can be used interchangeably with “grounding”.)

Not only does proper grounding provide a “point of zero” reference for determining voltages, it also functions as an “exit ramp” for stray or fault currents (or a runaway truck ramp, in the case of lightning strikes). Grounding is an escape route for unexpected electrical events to take before they can cause severe injury or damage anything -- from sensitive electronic equipment to entire structures.

Circling back for just a moment, this paper has thus far established broadcasting, *at its most basic level,* is 1) A function of creative manipulation of electricity, and 2) An endeavor which is dependent on highly competent engineering and management of very complex, expensive, and electrically sensitive equipment. It has also highlighted that proper grounding of electricity is both essential in making a desired flow happen, and prudent in terms of protecting equipment, structures…..and lives, when undesirable flows happen.

Given these points, the following discussion will explore the opinion that traditional grounding design, as used in the broadcasting business (and nearly all others), has not kept pace with electronic technology in common use today. Furthermore, the methodology used to create traditional grounding is overly assumption-driven, resulting in inaccurate, often fully insufficient, and unstable grounding strategies. What has sufficed as *acceptable* grounding in the past, simply doesn't fit well with the sensitivity and expense of broadcasting facilities and equipment now in use.

If you are a broadcast engineer reading this paper, stop for a moment and recall if your facility and/or towers – from studios to antennae – have suffered any electrical system damage over the past 10 or 15 years. If so, did these surge/spike events originate on inbound electric service, or from lightning strikes on or near facility structures? If you have experienced multiple anomalous events, have you noticed any change in the frequency of these events over the years? What type of equipment is usually at the “receiving end” of these events? With this in your mind, has the possibility of insufficient or inconsistent grounding capability been considered as a contributor to this damage? Finally, if so, what action has been taken to correct a grounding problem?

Addressing the last two questions just posed, it is highly likely IF grounding was seen as a contributor to damage, little action was taken, or if improvements in grounding were made, they were simple additions of traditional ground rods or grid arrays with rods to hopefully provide greater dispersion of possibly damaging fault currents. If there was extensive loss, a sincere attempt to seriously upgrade the grounding system was likely made, but ultimately, the grounding technology and methodology deployed was almost certainly based entirely on traditional rod-based solutions.

Conversations with broadcasting managers and engineers over the past few years have yielded the following general reasons for the above conditions and reactions:

- Generally speaking, grounding efficacy is an out-of-sight / out-of-mind issue: "It's just not a problem because our engineers and consultants have taken all *available and accepted* steps to prevent a problem. Nothing more can be done."
- Often, broadcast and electrical engineers are satisfied that there are no better alternatives to the use of common ground rods (with or without grid-arrays or soil amendments) for the purposes of mitigating electric system anomalies.
- For many years, lightning related losses have been considered expected costs of business in broadcasting. Elaborate and expensive grounding systems have been designed in….and if they don't work, back-up equipment (also expensive) takes over.
- In the pre-digital/HD days, the probability (frequency) of an electric anomaly loss times the cost of *relatively* simple equipment resulted in an essentially manageable expense Ground rod arrays – in spite of known, but not-well-defined shortcomings - *were* entirely suitable.

In order to explore these points more thoroughly, it will be helpful to gain a much better understanding of how traditional, *accepted* grounding designs are developed and deployed. Let's start with some of the most basic, long-standing *assumptions* behind grounding system design.

SPHERES OF INFLUENCE

In nearly countless publications, both web-based and in print, the *theoretical construct* of ground rod "spheres of influence" (also known as "interaction hemispheres", "resistance shells", and other terminology) is universally presented *as fact*. In spite of occasionally qualifying language, such shells or spheres are always illustrated as uniform in shape and dimension. For this condition to exist, surrounding soils must be *absolutely* homogeneous.

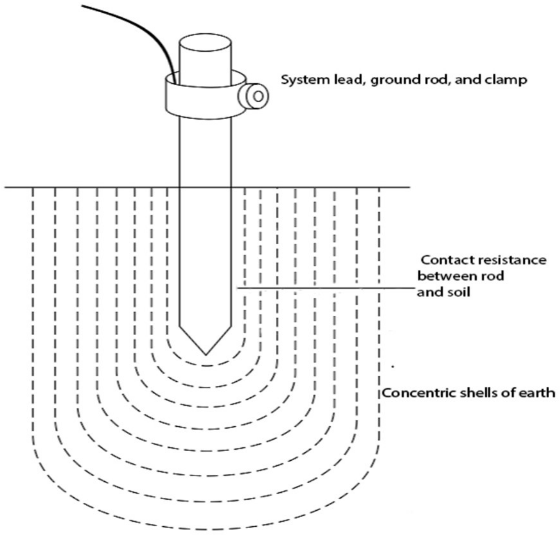

FIGURE 1: A REPRESENTATION OF SPHERES OF INFLUENCE

Of course, complete homogeneity is far less likely than is widely varying composition of soil in two or more layers, or combinations of soil types and environmental conditions in a small area.

So why is this important?

The answer is, *if* theories supporting design formulae and grounding system function do not reflect real world conditions, then application of these concepts and calculations in the field will yield unacceptable results, either in terms of performance or cost...or both.

In the sphere of influence example, underlying theory says the dispersal of current away from a ground rod is perfectly uniform along its entire length, and resistance to this flow becomes uniformly lower with distance away from the ground rod. Because of this assumption, most grounding system design guidelines (as well as the National Electric Code) recommend spacing driven ground rods a certain distance apart to avoid overlap of the "spheres" which reduces dissipation ability of the grounding system. This separation also can reduce the probability of a "ground loop" developing where unequal potentials within a grounding system can cause unexpected, damaging "upstream" flows, as opposed to full mitigation of a current into Earth. This condition is more common than might be expected. Interestingly, ground rod separation distance is not uniformly prescribed across accepted code, and grounding design manuals.

As already mentioned, to achieve this ideal uniformity of resistance and dispersion, for the entire length of the rod, soil composition (and therefore soil resistivity) must be entirely uniform. Additionally, soil temperature, and moisture content must also be perfectly uniform along the entire length of the rod, and even to a certain depth beneath the rod.

Clearly, this is not a likely event in real-world scenarios. Across the vast majority of the Earth's surface, soils can, and do rapidly vary with depth or distance from a point -- in composition, temperature, and moisture content. To expect a 6-meter ground rod to have perfectly uniform dispersal performance to a hemispherical depth and distance of up to 6 meters away from the bottom tip of the rod, AND within a cylinder of up to 12 meters in diameter with the rod centered in the grounding "cylinder is a fully unrealistic assumption.

Surprisingly, the same documents that promote the sphere of influence concept often also direct system installers to *ideally* drive ground rods deep enough to reach a known (presumably) constant level of ground water. Hence, in nearly the same breath, it is proposed ground rods have uniform performance, but the entire rod performs *uniformly better* if at least the tip reaches higher moisture soil!! This discrepancy in argument should cause concern for those seeking superb, highly consistent grounding performance.

Of additional concern, several very well-known grounding installation manuals and workbooks *do* point out soil conditions can dramatically vary in unexpectedly short distances and small areas, and state that designers of grounding systems should be aware of this. Then, *the same publications* revert to using the sphere of influence model and use calculations based on uniformity of performance regardless of soil conditions!

The above *spheres* illustration is presented in the vast majority of grounding manuals as a representation of resistance-to-ground for current flowing into a ground rod. In fact, this diagram is more accurately a representation of the electromagnetic field surrounding a ground rod, not resistance levels or current flows. As will be discussed in more detail below, actual *dissipation* of fault current along the length of a ground rod is directly related to the *frequency* of the current being carried in the rod ***and*** the conductivity of the adjacent soil. Because of these characteristics, as well as the homogeneity issue mentioned above, the validity of the commonly accepted "spheres of influence" model should be questioned.

Now….what is the relevancy of all this to the broadcast engineer and the facilities manager?

In practice, it is entirely possible for a single ground rod to have multiple, even independent, dispersion "spheres" of influence, and these would be of chaotic shape depending on soil resistivity at various depths and distances from the rod. Differing moisture and temperature also impact dissipation performance. Therefore, the expected performance of a single rod, or even a *complex* array of rods cannot be accurately estimated using an overly simplified performance model like the entirely *accepted* spheres of influence concept. To risk continuous and critical performance of a very complex "machine" (in the form of a complete broadcasting facility) on assumptions and theoretical concepts that do not reflect real-world conditions at all well…just isn't prudent. In the past, making "adjustments" and "compensating changes" to grounding design recommendations was considered appropriate. In today's world of highly current-quality-sensitive, very expensive broadcast equipment, a more certain and accurate approach to grounding design and deployment is needed.

Grounding is no longer only a mandated electrical system component. Instead, high performance, highly consistent grounding is a financially wise, essential business practice.

FURTHER ISSUES WITH UNREALISTIC ASSUMPTIONS

Currently, simple ground rods (often as appendages to equipotential rings and grids) are at the "business end" of the vast majority of grounding schemes used in broadcasting applications. Because these rods are known to have a limited ability to deliver stable and uniform performance in varying soil and environmental conditions, complete grounding system designs tend to be substantially overbuilt just to meet a fixed resistance-level target at a moment in time, generally upon initial construction. However, when environmental conditions change sufficiently, in spite of a certain level of design *compensation*, this type of grounding deployment frequently fails to protect.

To address potential failure of this nature, some grounding consultants recommend building as much as a 250% adjustment into the number or length of ground rods required in a system, as calculated by generally accepted design models – in order to account for the shortcomings of ground rods. That's a big premium to pay to ensure system efficacy. Furthermore, adding more of the same highly limited device to improve performance just doesn't make sense.

Again, the use of overly assumption-driven analytic methodology is at the root of such system design. As a second example of this condition, consider the following equation which is accepted by a variety of trade and academic organizations as suitable for determining resistance performance of a single vertical ground rod, in soil of a measured "average" resistivity, and of a specific driven length:

$$R_e = \frac{\rho}{2\pi l} \cdot ln\frac{4l}{d} \tag{1}$$

Where: R_e is the measured resistance to ground in Ohms.
ρ is average soil resistivity in Ohm-meters,
l is the length of a ground rod in meters, and
d is the diameter of the rod in meters

Generally speaking, graphed output from this equation, as well as from other very similar equations1 (when converted to English units) looks like Figure 2.

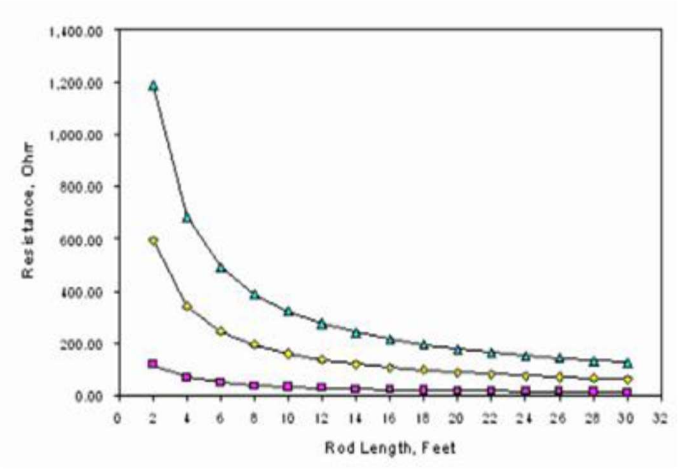

FIGURE 2: RESISTANCE-TO-GROUND FOR THREE SOIL RESISTIVITIES AND VARYING GROUND ROD LENGTH

In this example, rod resistance-to-ground is shown in soil with resistivities of 100, 500, and 1000 Ohm-meters (squares, circles, and triangles, respectively). Rod depths range from 2 feet to 30 feet, and rod diameter is 0.75 inches.

As in the sphere of influence example, this equation appears to have been created to model absolutely ideal conditions. As such, it suffers from several substantial real-world flaws:

- Average soil resistivity is a wholly undefined concept. Is the average resistivity that of soil in the immediate vicinity of the ground rod, or 30 meters away in a variety of directions, or perhaps average resistivity throughout a 60-meter square of land with the rod at the center? In all cases, over what depth of soil is this average calculated? Finally, and most importantly, is the soil perfectly uniform throughout the full area (and volume) measured?
- The equation appears to assume either 1) Moisture/ground water conditions throughout the sample area of soil will be entirely static and uniform over time; or 2) That the average soil resistivity figure used for determining resistance will properly reflect the moisture conditions in the future at the site. Unfortunately, neither assumption is suitable for a very large portion of the land area of the planet.
- Using the length of a specific ground rod in this calculation critically assumes dispersion performance of a ground rod is uniform along the entire length of the rod (as discussed in the *spheres* example). For this condition to exist, not only must the soil be perfectly uniform, it must also be of sufficiently low resistivity to lure/accept (again uniformly) electrons away from the ultra-low resistance of the metallic surface of the rod. While electrons are obviously attracted strongly to Earth and away from other negative charge, if the path to Earth, or the earthen soil in contact with the rod itself is highly resistive, dissipation performance suffers. Even along the minimal length of a 3-meter rod, varying or dramatically increasing resistivity, occurs far more often than reflected in accepted grounding formulae.
- In the situation where a ground rod is placed in high resistivity soil, as just mentioned, contrary to common practice, for purposes other than trying to reach a consistent water table level, length of a rod may actually be of little consequence in reducing overall grounding system resistance. Research conducted by the authors of this paper in multiple high soil resistivity locations in four US states has shown resistance *can* actually *increase* with greater ground rod depth, especially in gravely or rocky soil conditions. (Notably, when these data were seen, controls were put in place to ensure mechanical voids possibly created during installation were not the cause of increasing resistance. Follow-up testing several months after these installations confirmed the initial resistance results.)
- No consideration for frequency of current to be dissipated is given. This is a major oversight. Additional discussion on this matter is presented below.

When equations such as that shown above are then used to create further specifications regarding number and necessary depth of rods, severe propagation of error can occur. And such propagation means the probability of exposure to damaging or even catastrophic electric anomalies is unnecessarily, and perhaps significantly increased. Unfortunately, far too many grounding design specifiers use exactly this approach: The value of resistance-to-ground of a single rod, which in itself is subject to compromising error, is then assumed to be a suitable analog for the calculation of number of rods required, and total system resistance-to-ground of a multiple rod array – with these additional rods installed at various points (i.e. possibly varying soil conditions) throughout a grounding site.

A third example of accepted, yet overly assumptive design methodology, in Figure 3, we show a commonly used graphic calculation tool known as a “Grounding Nomograph”, where a desired target resistance to ground is selected, in this case, at 20 Ohms. Measured soil resistivity (likely a homogenized average) is shown as 110 Ohm-meters, and the ground rod being used is 5/8 inch in diameter. By using a straight-edge, the nomograph method indicates a 20 foot (approximately 6-meter ground rod) will provide the desired resistance.

Once again, however, highly unlikely simplifications have been built into this graphic calculation: Soil composition is assumed to be perfectly uniform, as is soil moisture content over time.

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[1] Another form of this equation is : $R_1 = \frac{\rho}{6.283L}\left[\ln\frac{8L}{d}-1\right]$

Should this nomograph represent the best-case scenario, then given the 250% range guideline mentioned above, the builder of a grounding system seeking 20 Ohms resistance-to-ground will need to install at least 65 feet of rods (and appropriate bonding) to provide proper protection if drought conditions sometime after installation happen to spike soil resistivity up to 300 Ohm-meters. (Dashed lines represent this case.). In that ground rod performance is highly impacted by soil moisture levels, this scenario is not at all unlikely.

But, again, all of this assumes rods and other traditional grounding methods dissipate exactly as "advertised" over the past half-century. Unfortunately, there is a growing body of evidence this is not the case. Additionally, installing many meters of rods is known to have severely decreasing effectiveness as length (or number of rods) increases.

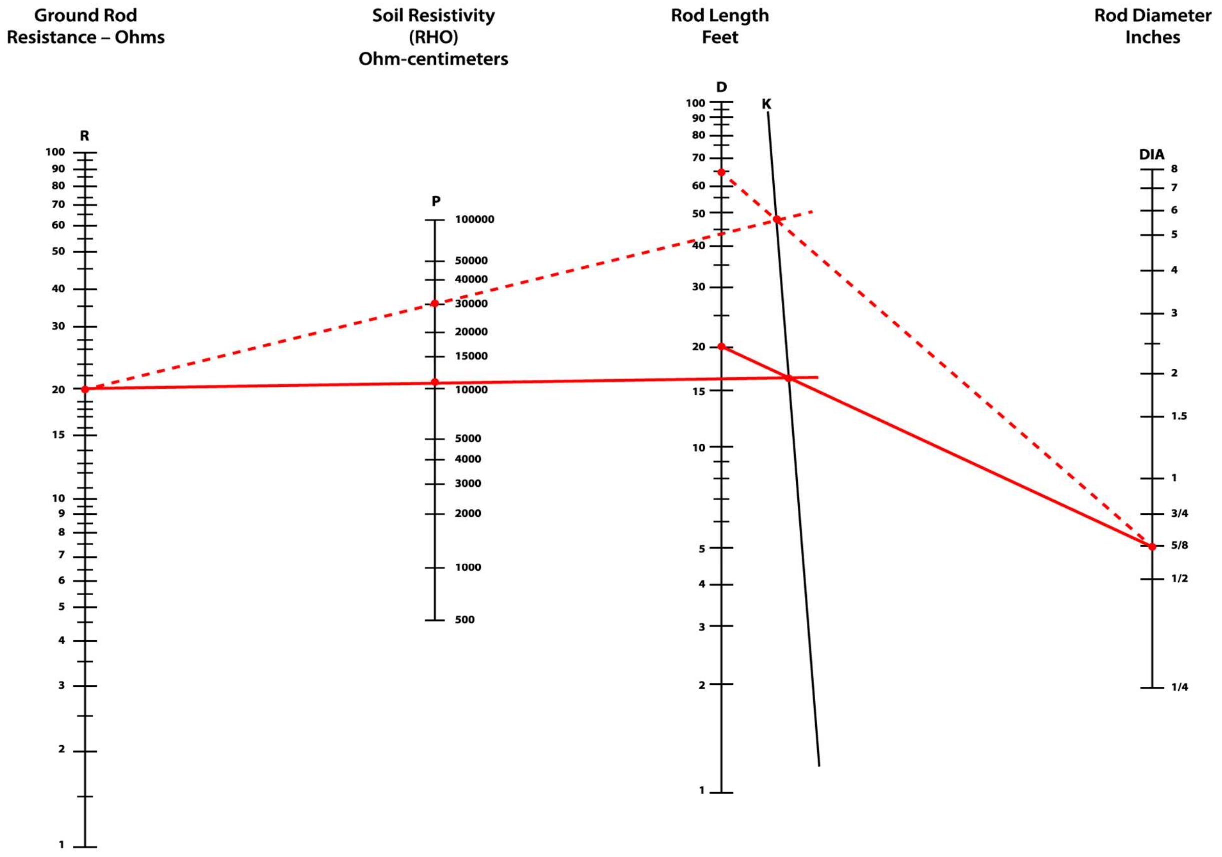

FIGURE 3: AN EXAMPLE OF A GROUNDING NOMOGRAPH

EXTREME CONDITIONS

Next, consider a scenario where soil resistivity is already relatively high, due *only* to soil composition. It is easy to see how a given grounding project to be installed in a challenging geologic setting can quickly devolve into a very expensive grounding system, often with dozens of ground rods, each additional of which makes a decreasing contribution to system resistance-to-ground – because in general terms:

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \dots + \frac{1}{R_N} \qquad (3)$$

Where: R_T is the total resistance to ground of the system in Ohms, R_1 to R_3 are the resistances of ground rods 1,2, and 3 in Ohms, and R_N is the resistance of the Nth ground rod in the system, in Ohms.

Said in more detail, high resistivity soils mean large numbers (or deep installations) of unstable-performance ground rods will be needed to reach a target system resistance. But as the number of rods increases, the marginal benefit of each rod drops. Hence, in terms of resistance reduction for the entire system, limited land area for grounding use comes into play. Additionally, as rod length increases, the probability of reaching essentially non-conductive rock grows. As discussed above, high resistivity soils focus dissipation on the extreme lower portion of a ground rod. If the rod tip reaches rock, resistance often spikes to the point of the rod becoming nearly useless to the system. Constructors of cellar communications towers, when bringing service to hilly or mountainous areas, must locate their towers generally on high ground. They are all too familiar with this situation. Many will quickly tell you all the fancy grounding models and equations, with their incumbent assumptions and simplifications, fall apart in a big hurry in extreme conditions such as very high resistivity, rocky soil. Sadly, operators of these tower facilities simply accept the consequences of damage, again assuming no other options exist.

IT'S NOT JUST RESISTANCE. FREQUENCIES MATTER

Entirely absent in the above analysis is the issue of the frequencies of fault currents. As stated many times above, traditional grounding is nearly entirely dependent at its dissipation points on arrays of ground rods. The concept of rod-based grounding is more than a century old, developed well before an even rudimentary understanding of lightning characteristics (and other surge/spike events) was known.

For standard 50- and 60Hz electric power, copper clad ground rods can work quite well, as copper is very suitable for carrying relatively low frequencies. In fact, copper is rather biased towards low frequencies versus high. Why? Because electrical charges occupy different depths from the surface of a conductive rod based on their frequency. This is known as the "skin effect depth", and is calculated as the inverse of the square root of the frequency[2] carried by the ground rod. Therefore, higher frequencies travel at shallower depths, and hence a greater portion of higher frequencies are carried at or near the surface of a ground rod. As such, higher frequencies have greater interaction proportionally with the less-than-desirable properties of soils surrounding a ground rod. The result is a noticeable decrease in the ability of ground rods to carry – *and dissipate* -- high frequency current.

This is critically important because anomalous, surge and spike events, including lightning, are generally filled with a wide range of frequencies, many of which can be in the Kilohertz (or greater) range. As an example, a typical 30kA return stroke of lightning can produce electrical current which peaks in 1-10 microseconds, easily introducing frequencies in the 100+ kHz range[3] (and a skin effect depth of less than 1/40 that of household currents). In this situation, right when grounding performance is absolutely necessary, traditional, accepted grounding strategies may be entirely insufficient, if not ineffective, regardless of measured system resistance-to-ground.

The bottom line of this for broadcast engineers is century-old grounding strategies may not be at all suitable for the sensitivity and complexity of contemporary broadcast facilities.

MEASUREMENT ISSUES

As a final point of concern with respect to bringing grounding up to date in the broadcast business, it should be noted measurements of soil conditions directly impacting grounding performance, and worse, measurements of in-service grounding system performance, are incorrectly undertaken far too often. And once grounding systems are in place, their performance is rarely again tested – right up to the time when a failure occurs, costing many thousands, or hundreds of thousands of dollars. In the broadcasting business, the latter magnitude is not uncommon.

Soil resistivity measurement has improved greatly over the last ten years, due mostly to the development of compact, accurate meters easily transported to, and used in the field. That's been a big help. But resistivity testing is a very time consuming, labor-intensive activity, which often causes field personnel to cut corners. Additionally, soil composition and moisture are rarely uniform through to the depths proper resistivity testing analyzes. Therefore, meters report an average resistivity between test probes. Traditional grounding design manuals generally specify a minimum of five resistivity tests must be run at various parts of the proposed grounding site in order to develop a sufficiently clear definition of actual site-wide soil qualities. Because of distances involved between test probes and repeated deployment of leads over these distances, such a process can take quite some time.

But even the "5-tests" recommendation may be insufficient for determining an accurate measure of resistivity for grounding purposes: The following points must be considered:

- Soil resistivity testing using the "Wenner" method creates a weighted average of resistivity between test probes **AND** at a depth up to one-third the distance between the most distant probes.
- As stated several times above, soils at a site may not be anything close to homogenous throughout the site, especially as depth increases.
- As averages (or "mathematical means"), statistically speaking, calculating averages *from* averages is not valid. Further, if a small sample size is used such as N=5, this condition is exacerbated.

But the biggest issue with Wenner resistivity testing is when tested depth dramatically exceeds the deepest point of the grounding system. In this case, resistivity at tested depth has very little to do with how the installed grounding system will actually perform. If substantial ground water is present at the test depth (beneath system depth), resistivity will be reported lower than the system will actually encounter. If the depth incorporates bedrock, resistivity will be higher than the system will encounter. Hence, both situations result in an inaccurate "ρ" value used in system resistance calculations. This, in turn, will yield incorrect results for the needed number

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[2] Jordan, Edward Conrad (1968), Electromagnetic Waves and Radiating Systems, Prentice Hall, page 130.

[3] 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. The authors report values from 0.3 to 0.37 microseconds, much lower than the commonly stated 1-10 microseconds used here.

of ground rods, rod placement, and overall grounding system performance. Therefore, focusing more on the resistivity of depths not greatly exceeding the "bottom", or deepest points of a proposed grounding system is essential for accurate resistivity analysis.

All this said, while soil resistivity is a very important consideration in grounding system design, it should be treated more as a guideline with emphasis on shallow depths, than as a critical input variable in determining system layout and predicted ground rod (and total system) resistance-to-ground. As for *resistance* (as opposed to resistivity) testing of an *installed* grounding system, the manner in which systems are tested, and the frequency of future testing are concerns. In too many cases, testing of a grounding installation is performed in a totally inaccurate manner, quite simply because many technicians (surprisingly including professional engineers) don't have information on how the system is designed, or they don't have the proper equipment. The authors of this paper have witnessed this situation extremely frequently. Completely erroneous reporting of system resistance is the result. For a broadcaster, this is obviously very dangerous, and a risk not worth taking.

With respect to on-going testing, in practice, once a grounding system is deployed, further performance testing of the system is very rarely undertaken. Yet with the purchase of relatively inexpensive test equipment, broadcasters can proactively engage in highly effective risk management of a critically important, but hugely overlooked, component of their facilities. A good "best practices" guideline would be to test grounding performance quarterly, and perhaps more frequently when drought conditions are being experienced. (Lowered water tables and soil moisture levels can play havoc with nearly all traditional grounding systems.) In a matter of minutes, the "health" of the best insurance policy a broadcaster has against electrical-related damage can be monitored. Any expense incurred pays off with *the first* properly mitigated fault current.

Overall, considering the sensitivity and the expense of millions of dollars of electronic equipment in a broadcasting facility, from camera to antenna tip and everything in between, careful, correct, and regular analysis of electrical grounding present is quite simply a smart play.

SUMMARY

Interestingly, one might think with the use of common traditional grounding for well over a century, there would be full agreement regarding maximizing the safety and capacity of such systems. The preceding discussion underscores that is not at all the case. There are frequent disagreements among engineers, manufacturers, and consultants on some of the most basic concepts in grounding. Notably, some highly regarded specification manuals substantially overlook or fail to emphasize a variety of design criteria recognized as essential by other manuals or organizations. Confounding this situation further, models and equations constructed for analysis and deployment of traditional grounding methods do not reflect real world conditions very well. Thus, in spite of tremendous efforts to mathematically generalize the practice of grounding design, the reality is *every grounding solution is unique.* Each installation faces a myriad of independent variables and conditions that can easily overrule the best efforts of code-writers, analysts, and engineers claiming mastery of grounding techniques.

This combination -- every grounding site having unique, changing characteristics, and there being a surprising disparity in grounding methods and procedures – highlights the need for a more flexible and innovative approach to creating more universal, site-tolerant grounding solutions. Consensus-driven traditional rod designs that don't respond well to outlier events and non-stable site conditions far too often result in failures of protective systems, and hence very expensive repair and replacement of sensitive equipment, or even off-air events.

Furthermore, up until now, using inaccurate theoretical concepts, simplified equations, and specification directives which overlook proper system measurement, has been considered *acceptable* for grounding design. However, with the costs and frequency of losses due lightning and other electrical-related events increasing dramatically[4], such practices are quickly becoming *unacceptable.* These costs and losses are clear evidence of the shortcomings of traditional ground rods and accepted analytical techniques underlying their deployment. Therefore, changing the way grounding solutions are envisioned and applied appears to be imminently necessary.

With respect to broadcasters, whether public safety, small town FM, mobile communications, or major- market television, the functional and financial benefits available from adopting new approaches to grounding solutions are very easy to see. A completely new look at electrical grounding is warranted.

For more information on the advantages of improved analysis of grounding and dramatic innovations in grounding techniques, we encourage you to contact our company directly, or visit our website.

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[4] . Data collected by the Insurance Information Institute state that claims for lightning related damage increased by 77% between 2008 and 2016. Claims paid for lightning and other electrical anomalies now exceed $800 million annually in the United States.