10 Common Misconceptions for Grounding Analysis

INTRODUCTION

An important aspect of a grounding system design is personnel and public safety. It is important to reduce the misconceptions regarding grounding system design, as personnel are dependent on these buried systems and typically unable to directly evaluate their condition while on-site. Grounding system performance is affected by multiple variables simultaneously, often resulting in designs unique to a site. This makes standard grounding system designs practically impossible, highlighting the need for proper guidance in the design of these complex systems.

1 – Grounding System Performance Fluctuates

It may not be apparent, but local site modifications such as new breakers, transformers, and general layout changes as simple as fence-line modifications could result in touch voltage hazards in previously compliant sites. Additionally, offsite utility system changes may affect the performance of a grounding system. The addition of a new switchyard, transmission lines, or generation may increase the power system fault current availability and corresponding touch and step voltage hazards.

Additionally, soil resistivity may vary significantly based on the seasonal and climatic changes at a site, which significantly affects the grounding system performance. Figure 1 shows most of a system is within permissible limits, in green, but as ambient temperatures decrease, the native soil resistivity increases resulting in exceeding permissible touch voltage limits throughout the site, shown in Figure 2.

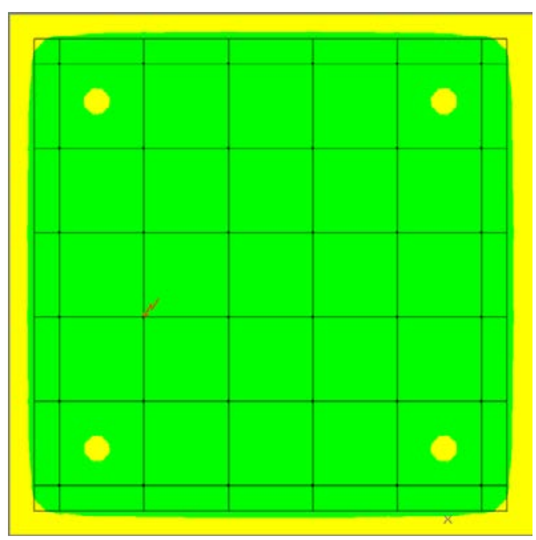


Figure 1. Summer Grounding System Performance

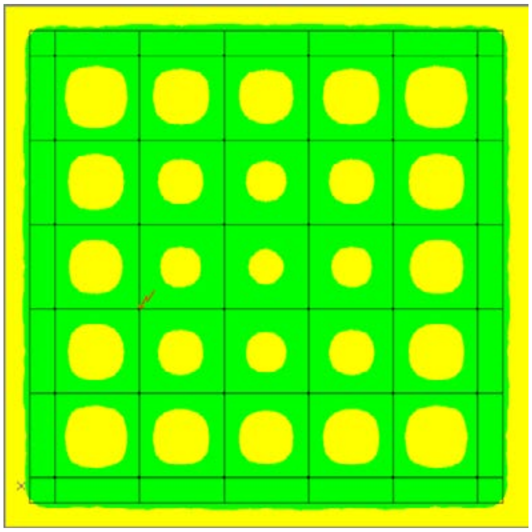


Figure 2. Winter Grounding System Performance

Consider these performance fluctuations with safety margins in the design and use of Seasonal Analysis tools from XGSLab to forecast seasonal performance.

2 – Assumed Soil Data

Tables and references for typical soil resistivity values are widely available and provide ranges for the expected conductivity of various soil types based on the visual characteristics of the soil. While it may be very useful to reference typical soil resistivity data for affirming measurements, these values cannot be used for final grounding system designs.

As an example, while a material may be visually characterized as sandy clay, typical resistivity may be as low as 50 Ω-m or as high as 300 Ω-m. The resulting ground potential rise could be six times larger assuming a soil resistivity on the lower end of this range, while higher resistivities could result in higher permissible touch and step voltages.

Table 1 shows the effects for the same grounding system design when assuming a lower versus higher soil resistivities.

Table 1. Assumed Soil Model Outcomes

Soil Resistivity	50 Ω-m	300 Ω-m
Impedance (Ω)	0.49	2.88
Ground Potential Rise (V)	4,855	28,853
Permissible Touch (V)	280	381
Permissible Step (V)	340	745

3 – Soil Measurement Errors

Soil resistivity test values are simple to perform, but there are several ways the testing can capture errors leading to poor grounding system designs. Typical soil resistivity measurement errors are related, but not limited to, probe continuity, test device limitations, and interference. If undetected, erroneous soil resistivity test values can result in inadequate grounding system designs, or significant overdesigns.

Poor continuity of the test probes may be detected by the test equipment's error reporting, but often the testers must evaluate the measurement results. Additionally, testing devices vary in their power and sensitivity and persons performing soil resistivity tests must be aware of their devices' capabilities. A piece of test equipment that works well in one region may have challenges in another. Adding saline solution to the probes or connecting additional probes in parallel at test locations may improve continuity between the soil and test device measurements.

Signs of erroneous soil resistivity measurements include soil resistivity values outside of normal ranges or rising calculated soil resistance values at increasing depths. Table 2 shows a table of soil resistivity measurements with an error in the 40 foot "a-spacing" value as soil resistance should decrease with increasing depth/probe spacing.

Table 2. Erroneous Soil Resistivity Measurements

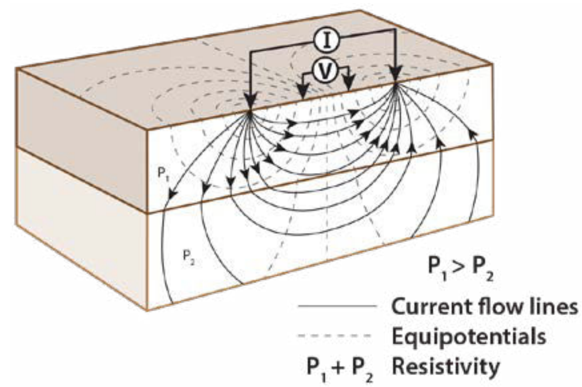
Probe A-Spacing (ft).	Resistance (Ω)
1.5	11.39
3	5.79
5	3.41
10	1.62
15	1.06
20	0.81
25	0.63
30	0.52
40	0.63
50	0.32
70	0.2
90	0.2

Note - Values in red indicate errors

Soil resistivity testing should not be performed over or immediately adjacent to an existing grounding system, as the injected test current will enter the metallic grounding system, skewing measurement of the native soil. Physical interference occurs when metallic objects such as metallic pipes or fencing within the hemispherical range of the measurement traverses lead to inaccurate results. Performing perpendicular measurement traverses allows for testing personnel to detect this type of interference.

4 – Insufficient Soil Test Arrangement

Soil resistivity should be measured to a sufficient depth such that effects related to vertical soil resistivity stratification on grounding system performance are analyzed. Increasing the soil resistivity measurement traverse lengths yields more information about the stratification of soil resistivity at increasing depths. Conversely, shorter traverse lengths yield information about the soil resistivity at shallower depths. Larger grounding systems have increased zones of influence and thus require longer traverses of soil resistivity measurements. The IEEE Std 81-2012 indicates that taking soil resistivity measurements to insufficient depths may result in grounding system being under designed by as much as 110%.



At a minimum, soil resistivity should be measured to a depth equivalent to the diagonal distance of the overall grounding system, or an appreciable percentage of this distance as feasible. If soil resistivity changes are observed with increasing depth, greater depths (longer measurement traverses) are recommended. Similarly, engineers performing grounding system design for geographically large facilities may consider taking multiple separate soil resistivity measurements at different locations throughout the facility to characterize horizontal changes in soil resistivity.

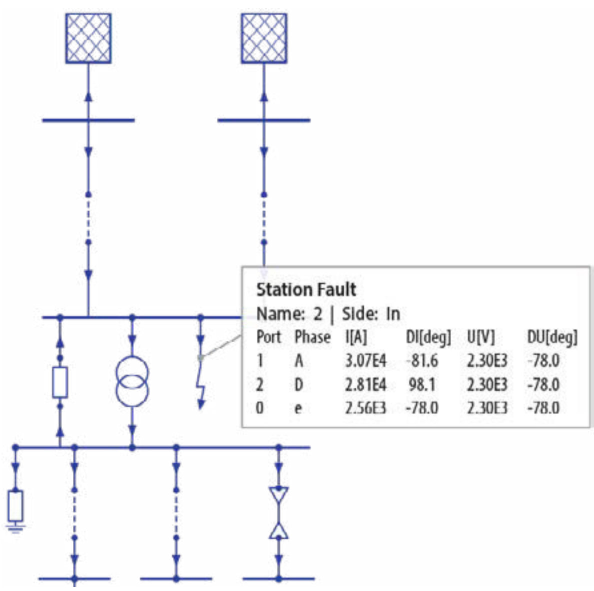
5 – Ground Current Necessary for Ground Potential Rise

Fault information is typically simulated from a utility's power system model, including fault current magnitude, clearing time, and X/R ratio for each voltage level at a facility. A common misconception is that the three-phase fault current should be used for evaluating grounding system performance. Ground current is necessary to produce a ground potential rise and cause the corresponding touch and step voltage hazards to occur. Three-phase faults do not have a zero-sequence current component and therefore will not produce touch nor step voltage hazards throughout a site.

Ground current (zero-sequence current) is present during single-line-to-ground faults and double-line-to-ground faults. For either of these fault conditions, engineers should evaluate touch and step voltages hazards.

6 – Fault Current Split

For many ground fault events, a portion of the current will take alternative paths that do contribute to a ground potential rise (GPR) of the grounding system under analysis. Determining the fault current split provides the percentage of fault current that goes through the grid producing a GPR and the portion that takes alternative paths reducing the maximum GPR. Considering the fault current split allows for a more accurate analysis and more efficient grounding system design. Alternative paths often include a transmission line's overhead wires, distribution neutral wires, and cable shielding and armor. There are several methods for calculating the fault current split, but a common simplified approach is to calculate or reference the equivalent impedance of the alternative paths and enter those R_{eq} and X_{eq} values into the XGSLab split factor tool.



More thorough investigation is performed by software, such as NETS, that use the phase component method to model a complicated meshed power system such as multiple stations feeding a fault at a substation. The NETS model shows a 30.7 kA phase A fault, but only 2.56 kA will produce a GPR (through e) with the remaining taking the transmission shields and cable neutrals paths (D).

7 – Remote Versus Local Fault Contribution

Grounding system studies refer to a remote source as a system that when sufficiently far from the site under evaluation there is no resistive coupling.

For many substations, the high-voltage fault is sourced from remote stations as illustrated in Figure 3, where ground current travels through the grounding system resulting in a ground potential rise.

Note that current returning through the earth path at the source-end of the electric system also yields a ground potential rise at the source, which is discussed in the next section.

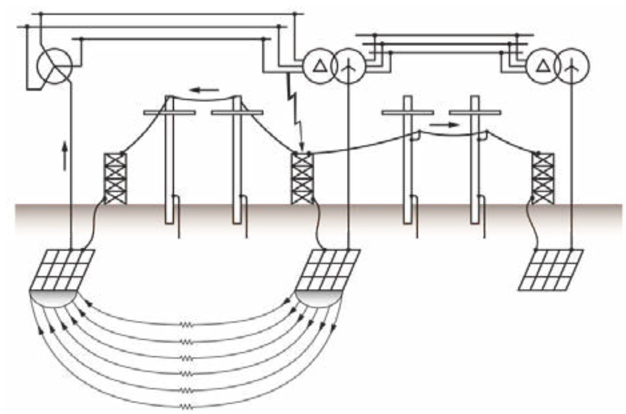


Figure 3. Remote Fault Source

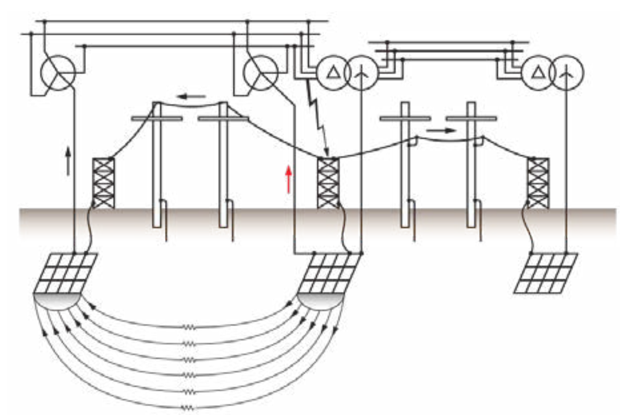


Figure 4. Local Fault Contribution

When a local source contributes to a fault, that current will return via directly connected metallic paths back to its source and does not contribute to the calculated touch and step voltage magnitudes, as shown in Figure 4.

Local sources of ground fault current include generators, autotransformers, or other local delta/wye-grounded transformers where low-side ground faults may return to the transformer neutral.

The local fault contribution may be more than 50% of the total ground fault current. Analyzing only faults that occur locally on the site will underestimate the touch and step voltages as a remote ground fault can produce the largest ground potential rise and possibly the worst touch and step voltage hazards. Engineers should consider both local and remote ground faults when designing grounding systems to ensure that worst-case conditions for touch and step voltage hazards are assessed.

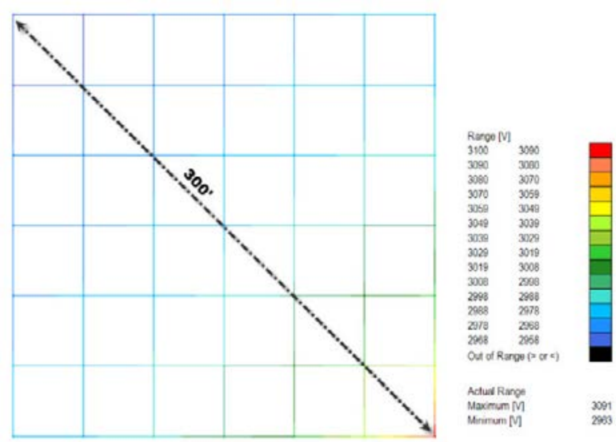
8 – Intermittent Touch Voltage Hazards

For touch voltage hazards to be present, there must be a grounded, metallic object that personnel may touch. In power systems, some areas with significant voltage gradients may not require grounding conductor if there are no objects in the vicinity to touch. This allows for optimized grounding system designs that protect individuals from touch voltage hazards only in selected locations. Objects such as service vehicles, temporary equipment, and fence gates may be intermittently present in certain locations. Grounding systems should provide personnel with adequate protection from touch voltage hazards for intermittently present objects. When reviewing a grounding system design, the presence of ground loops extending out to encompass the swing of gates are a good indication of a proper design that accounts for intermittent objects.

9 – Software Calculation Methods

Computer calculations offer numerous advantages when compared against hand calculation approaches to grounding system design. Several software solutions exist that provide simple methods for evaluating grounding system performance and many users may not realize that many software tools incorporate assumptions into their calculation approaches. For some sites, these assumptions made by software solutions can result in false indications of compliance (or noncompliance) with touch and step voltage limits.

A common assumption for first generation grounding software use of a "superconductor" where they ignore the voltage drop on the ground grid. Often referred to as equipotential plane, using the wrong analysis could lead to dangerous under-design, or expensive over-design. XGSLab calculates self and mutual impedances, showing the 100V+ difference of the ground grid.



Contact Sales@easypower.com to request our "Limitations of Simple Grounding Software" guide for more details on simple software limits!

10 – Sampling Earth Surface Potentials

Analysis tools allow for precise calculation of the earth's surface potentials to determine touch and step voltages. The calculation of the earth's surface potentials is commonly evaluated by sampling at specified steps or spacings and most commercially available software can adjust this criterion as different sampling amounts may be necessary for different sites and evaluations.

Figure 5 shows an adequately dense sampling of potentials with multiple points moving outward from one ground conductor to the next.

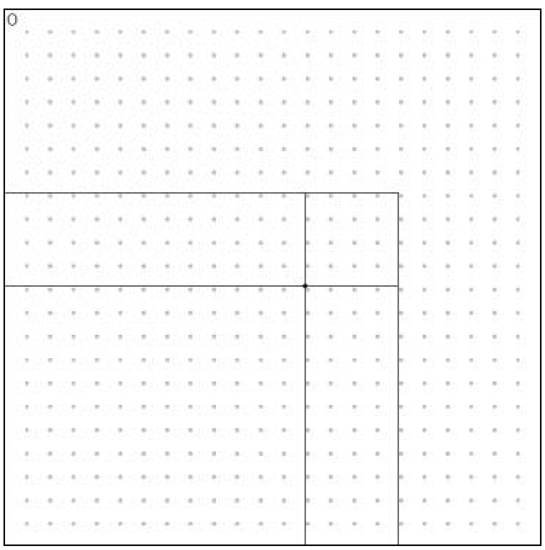


Figure 5. Dense Earth Surface Potential Calculations

Figure 6 provides an example of a sparse calculation, with few analysis points from one grounding conductor to another, missing maximum and minimum earth surface voltages.

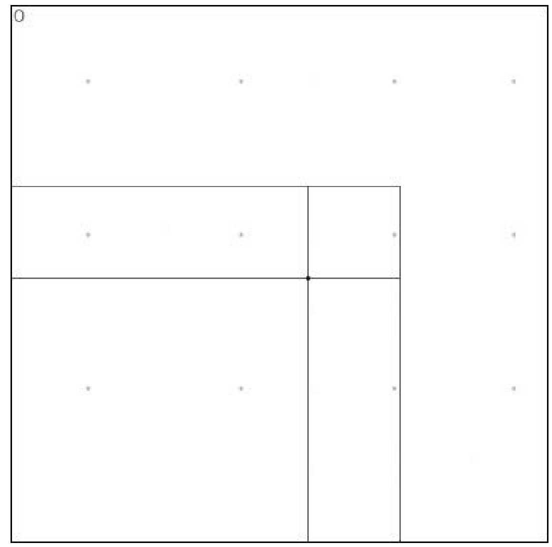


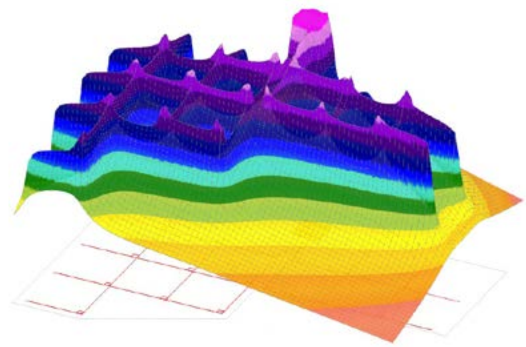
Figure 6. Sparse Earth Surface Potential Calculations

Sparse calculations of earth's surface potentials are more likely to miss the maximum and minimum surface potentials' locations, which typically correspond to the worst-case touch or step voltage hazards

XGSLab Software

XGSLab is one of the most powerful software packages for grounding system analysis, electromagnetic fields, AC interference, and lightning analysis. It is used worldwide for:

- Grounding System Analysis
- Multilayer/Zone Soil Models
- Below and Above Ground Systems
- Cathodic Protection Systems
- Magnetic & Electric Fields
- Electromagnetic Interferences
- Fault Current Distribution
- Lightning Shielding and Analysis
- Time and Frequency Domain



Applications

The following table summarizes the main applications of the available models.

	XGSLab Modules					
	GSA	GSA_FD	XGSA_FD	XGSA_TD	NETS	SHIELD
Grounding (equipotential systems)	✓	✓	✓	✓		
Grounding (general conditions)		✓	✓	✓		
Cathodic Protection Systems		✓	✓	✓		
Magnetic Field		✓	✓	✓		
Electric Field			✓	✓		
Electromagnetic Interferences		✓	✓	✓	✓	
Corona Effects			✓			
Switching Transients, Lightning and Fault Transients in GIS				✓		
Steady State Solver for Full Meshed Multi-conductor and Multi-phase Networks					✓	
Short Circuit Current on Full Meshed Multi-conductor and Multi-phase Networks					✓	
Fault Current Distribution on Full Meshed Multi-conductor and Multi-phase Networks					✓	
Lightning Shielding						✓

Contact Sales@EasyPower.com to get answers to any questions or set up a one-on-one free demo of the capabilities of the XGSLab software. You can also **request a quote** (www.EasyPower.com/quote). You can learn more about XGSLab by visiting our website at: www.EasyPower.com/grounding

For more resources to help you with grounding, lightning and EMF needs, visit the EasyPower website and go to the **Grounding Resource Center**.

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