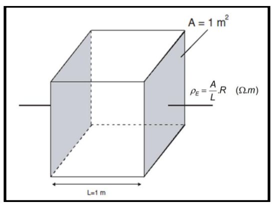
Surge Protection for Electronic Equipment with Unreal Ground Resistance Demands

By Bruce Glushakow, MCG Surge Protection.

Ground Resistance is the term used to describe the resistance of an electrical system's ground connection and is typically expressed in units of Ohms. More precisely, ground resistance is the amount of difficulty electricity has in passing between two opposite sides of a cube of soil with edges 1 meter long.



Every engineer planning to retrofit a broadcasting or telecommunications site or planning to construct new sites, is faced with this question: *how low must the ground resistance value be in to assure good lightning surge protection for the electronic equipment?* One might dream of having a ground resistance of zero ohms, but since that is physically impossible, various standards and industries have put forward different preferential ground resistance values. MIL-HKBK 419A advances the figure of 10 ohms as does IEC 62305-3 and many tower contractors. The telecommunications industry often seeks to achieve 5 ohms. Wind turbine vendors have been known to request 2 ohms. The U.S. National Electrical Code (NEC 250) suggests but does not require ground resistance be kept below 25 ohms.

FACTORS THAT CONFUSE THE ISSUE OF GROUND RESISTANCE

There is no "perfect" ground resistance value. Any and all proposed numbers are compromises between the expected uses of the ground (whether for fault current, lightning protection or signal line reference point) and the estimated relative cost of achieving that resistance in typical situations. Three factors that further confuse the issue are:

1) Even when a broadcasting network's engineering staff has decreed a "5-ohm" ground resistance figure for its base stations, Mother Nature can often be counted on to stand in defiance. In rocky soils, on promontories overlooking the sea, and at broadcasting/ telecommunication mountain sites (to name some examples) it can be impossible to reach a true ground resistance of anywhere near 5 ohms.

2) Establishing an accurate repeatable ground resistance value at difficult sites is problematic. It is possible to improve ground resistance values by varying the length, diameter and composition of the ground rods, the number of ground rods employed, and the depth the ground rods are driven into the earth. But the issue is complicated by the fact that the resistance value of an earth electrode (ground rod) is a function of the composition and density of the soil at the exact location of the ground rod, how much moisture is in the soil at time of measurement, plus the temperature at time of measurement. These values can change from hour to hour, season to season and at different depths in the ground making repeatability of test results a problem. Ground resistance values can fluctuate within such wide limits that variations of 20% are generally ignored. This makes it easy to cheat: the earth around the ground rods can be soaked with water before a test or the ground rods can be packed with chemicals that may ensure a good 'test result' but soon leach out into the surrounding soil.

3) If you're a telecommunications or broadcast engineer, or anyone in charge of sensitive equipment uptime, you dread an SPD failure. SPD manufacturers, whose products have failed at their job of protecting electronic equipment from lightning surges may attempt to shift blame: "It's not our fault; it's the fault of your grounding. You need to improve it to 5 ohms or 3 ohms or 1 ohm." Not so.

THE IMPORTANCE OF EQUIPOTENTIAL GROUNDING

NFPA sums up the ground resistance issue as follows: "low resistance is desirable, but not essential." The goal in ground resistance is to achieve the lowest possible resistance value with due regard to the physical conditions at the site and the available budget.

One reason for the notoriety achieved by the subject of ground resistance is a hopeful theory that states: "the lower the ground resistance, the easier will high energy from lightning strikes dissipate into the ground." Unfortunately, that's not the case. From the viewpoint of lightning protection, a single integrated earth termination system with all grounds electrically bonded together, is far senior in importance to any arbitrary "ground resistance" value.

When all equipment and conducting services are connected to a more or less equal potential plane, you ensure the minimum potential differences between the towers, buildings and equipment within the protected area. Equipotential bonding ensures there will only be a difference of a fraction of an ohm between the different metallic conducting parts of a system instead of the several ohm difference that exists when the individual metallic elements of the system are not bonded together. Equipotential bonding is key to obtaining safety for both people and electronic equipment.

Bonding means permanently connecting the different metallic parts of the earthing/grounding system together. The equipotential bonding consists of a main equipotential bonding bar (MBB) where all conductive elements at the site are directly connected. They include (but are not limited to):

1. Main equipotential bonding conductor
2. Ground rods (earth electrodes)
3. Conductive parts of the building structure (e.g. lift rails, steel skeleton, ventilation and air conditioning ducting)
4. Metal drain pipes
5. Internal metal gas pipes
6. Earthing conductor for antennas
7. Earthing conductor for telecommunication systems
8. Protective conductors of the electrical installation (PEN conductor for TN systems and PE conductors for TT systems or IT systems)
9. Metal shields of electrical and electronic conductors
10. Metal cable sheaths of high-voltage current cables up to 1000 V

The need to ensure an equipotential plane becomes obvious by the following simple calculation: When a typical lightning current of 10 kA is injected into an earthing system with an impedance of only 1 Ω, a potential voltage rise relative to the earth of 10kV will be evoked. ($U = I*R = 10.000A \times 1\Omega = 10,000$ V) Such a voltage spike would cause a flashover capable of destroying any electronic equipment connected to the circuit when bonding has not been properly done. That's an example of the result of just 1 ohm resisting a small surge current. But a single lightning strike can reach a level of hundreds of thousands of amps and you might have to settle for 20 ohms of ground resistance in mountainous sites. Here's what can be done.

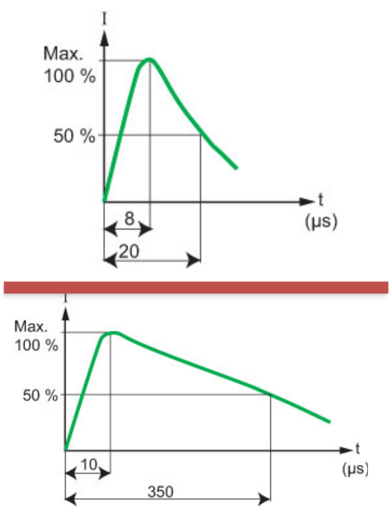
Resistance vs. Impedance

Resistance and impedance are both calculated the same: R = V/I. But they have different origins and different applications. Resistance applies to direct current, while impedance encompasses not only resistance but also other types of electrical interference characteristic of alternating currents.

Impedance is often cited as senior to resistance in lightning protection strategies, but the fact is that lightning is composed of direct currents, not alternating, so it can be argued that an emphasis on impedance somewhat muddies surge protection waters with over-complication. This does not minimize the importance of such strategies as employing multiple ground rods, keeping surge protective paths short and straight, and using appropriate cable diameter, but these could just as easily fit into a category called 'aiding the rapid dispersal of lightning currents into the ground' without entering into such arcane abstractions as reactance, capacitance, transmission theory, etc.

Lightning waveforms: The real and the imaginary

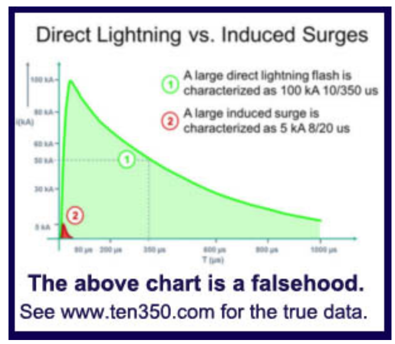
Perhaps the main reason some people have assigned unwarranted importance to the subject of impedance is that by doing so, they got to focus attention on the factors of the rise time and decay time of electrical waves. As it applies to lightning, rise time is the time (in microseconds) that it takes for a wave to reach its maximum amplitude (sometimes reckoned in standards as 80% of its peak amplitude.) Decay time is the amount of time (also in microseconds) that it takes for a wave to diminish down to 50% of its peak. Here are diagrams of the two waveforms most commonly associated with lightning: the 8/20 waveform and the 10/350 waveform.



The waveform above the red line is the 8/20. It roughly agrees with the results of many studies and measurements of lightning that have been made by meteorologists and lightning scientists throughout the world.

The waveform on the bottom is the 10/350. It is a fabricated waveform for which there is no evidence of any existence in nature. The world's premiere lightning study (CIGRE's Technical Bulletin 549 issued in 2013) included 16 warnings against considering the 10/350 waveform as representative of actual lightning or using it for engineering purposes. See the website http://www.ten350.com for the full story.

What happened in the world of lightning protection is that despite the fact that there is no scientific evidence of its existence in the real world, commercial interests latched on to the idea of a 10/350 waveform as a "scientific" means to justify the use of their spark gap products. Spark gaps do poorly in any high amplitude or multiple impulse tests using the 8/20 waveform. Because they respond so slowly spark gaps required a test wave with a rise-time 25% longer than the 8/20 to give the spark gap time to respond. The 10/350 waveform exactly fit that bill and was interjected into IEC lightning standards despite the fact (or because) it exactly parallels the inefficient operating characteristics of the spark gap. Every spark gap manufacturer in the world uses a variation of the diagram above to "prove" that surge protectors must be tested with a 10/350 waveform because "only the 10/350 waveform is representative of direct lightning." The statement is a falsehood. Using it to discredit the far more effective MOV-based surge protectors has resulted in tens of millions of dollars in damaged equipment and lots of upset customers.



(Note to telecom engineers: every single site where you have experienced damage from lightning was protected by a spark gap surge arrestor which "passed" tests based on a 10/350 waveform.)

"Better late than never." -- the aphorism that does NOT apply to surge protection

If you've ever had anything to do with putting out fires, you know that the first law of firefighting is to **put it out fast**. A delay of just seconds or minutes can mean the difference between an extinguished fire, and a conflagration raging out of control. It is the same with surge protection and explains one of the reasons MOVs are so effective. MOVs respond in a couple of nanoseconds and are able to continue to respond for thousands of repetitive operations. In comparison, it can take a threshold voltage of 3,000 to 4,000 volts to trigger a spark gap operation and a spark gap's response time can vary from 100 nanoseconds to several microseconds. These are some of the reasons spark gaps allow such high let through currents and voltage. To put it simply, MOVs begin to put out the fire 100+ times faster than any spark gap.

Surge protectors: Home Improvement Store Varieties vs. Industrial Grade

The SPDs specified by IEC lightning protection standards can only be described as lacking. At best they may be able to clamp a few moderately sized transients down to safe levels, but only if the site's ground resistance is in the vicinity of 5 ohms or less. Why the limitation? Because the higher the ground resistance, the more strain is placed on the surge protector. Light-duty SPDs simply do not have the tolerance to operate under the stress of real lightning environments. This accounts for their typical lifetime of only 1-3 years.

There is another type of surge protection—**Industrial or Professional Surge Protection**--that is built to deal with real world lightning stresses. Some of the features that are designed into a professional surge protector that enable it to stand up to the operational stresses existing in harsh lightning environments include:

- Fast acting--100 times faster response time than any spark gap
- Multiple individually-fused redundant protection paths on every phase
- A healthy respect for actual size of lightning. 80kA to 250kA for telecommunication and broadcasting networks as opposed to 50kA because that is what is needed to provide dependable protection.
- The joule ratings of a professional surge protector will be found to be 10-20 times that of subpar SPDs.
- Any professional surge protector will be tested to withstand 10,000 surges and last for 20 years.
- No spark gaps included in any Professional Surge Protector nor any specs using a 10/350 waveform.
- Internal copper bus bars create low impedance paths to ground

Lightning Protection Systems and Surge Protection Systems.

There is an important difference between these two systems. A lightning protection system consists of air termination points (lightning rods), down conductors, bonding belts and ground rods. A Surge Protection System consists of Surge Protectors (SPDs)--devices with protective elements that limit overvoltage levels to a range safe for connected electronic equipment.

Fifty years of field experience has proven that the best lightning protection systems in the world are unable protect electronic equipment from lightning damage without the installation of effective professional surge protectors. Another lesson learned is that even a mediocre grounding system with relatively high ground resistance values is adequate to fully protect electronic equipment from the effects of lightning and other sources of transient surges so long as a well designed and constructed professional surge protector has been installed. For this reason, it makes sense to spend not less than 1/2 one's overall lightning protection budget on Professional Surge Protection Devices.

#end#

Low-end surge protectors are not a path to achieving professional-grade surge protection. If you provide a single integrated grounding system and use highly reliable, rugged surge protection, you can ensure perfect protection for your equipment whether your ground resistance is 1 ohm or 30 ohms.

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