2014
23rd International Lightning Detection Conference
18 - 19 March • Tucson, Arizona, USA
5th International Lightning Meteorology Conference
20 - 21 March • Tucson, Arizona, USA

THREE ESSENTIALS OF LIGHTNING PROTECTION: BONDING, GROUNDING AND SURGE PROTECTION

Richard Kithil, President
National Lightning Safety Institute (NLSI)
Louisville CO USA
rkithil@lightningsafety.com

Orlando Alzamora, Vice-President
National Lightning Safety Institute (NLSI)
Miraflores, Lima Peru
oalzamora@lightningsafety.com

Abstract: Bonding, Grounding and Surge Protection are integral parts of a topologically shielded lightning protection system for reasons of codes compliance, good engineeering practices and safety. This Paper describes their respective roles, with citations from important international Codes and Standards.

1.0 Introduction. Lightning protection, like a gourmet recipe, requires thoughtful attention to selection of ingredients, to combining them properly, and to the presentation or serving of the completed design. Cookbooks (i.e. Codes & Standards) generally describe lightning protection systems (LPS) as consisting of several components:

1.1 Air Terminals which may or may not "collect" the lightning.
1.2 Downconductors to direct all or some or none of the lightning.
1.3 Bonding which unifies all conductors.
1.4 Grounding which provides a low impedance destination.
1.5 Surge Protection Devices (SPDs) which defend critical circuits/operations against transients.
1.6 Inspection, Maintenance and Testing.

This Paper suggests that Air Terminals (AT) of whatever types including Conventional as well as Unconventional designs play a limited, even exaggerated, role in overall lightning protection of contemporary assests, facilities and structures. By examples consider an AT with downconductor wire on a steel radio tower or an AT with downconductor on an aluminum framed building. Instead, without elements of topological shielding -- bonding, grounding and surge protection -- safety from the effects of lightning may not be assured.

2.0 BONDING.

Detailed attention to bonding of all conductors assures that unrelated or adjacent metallic objects are at the same electrical potential. Without such equi-potential connectivity lightning protection cannot be reliable. Voltage rise mis-matches will ocurr which may cause dangerous arcing. This may cause interruptions to circuit regularity. And sparking in the presence of combustible objects may lead to fires.

All metallic conductors entering structures such as AC power circuits, gas and water piping, data and signal sources, HVAC ducting, exterior conduits and piping and ladders, railroad tracks, overhead bridge cranes, roll up doors, metal door frames, hand railings, etc. etc. (…the list is a long one…) should be electrically referenced to the same single ground potential. So too should lightning air terminals and downconductors. This is mandated by the USA National Electrical Code NFPA-70, Section 250. XX.

Each facility or structure is unique and different. Careful attention should be given at the design stage and at final construction. Connector bonding should be exothermal and not mechanical (bolted) wherever possible, especially in below-grade locations. Mechanical and bolted bonds are subject to corrosion, physical damage and looseness due to temperature differentials. Compression bonding is acceptable in many cases. Frequent inspection and measurement of cross-joint connections to assure continuity is recommended. A measured minimum one ohm bond usually is satisfactory per requirements of the US Air Force AFI 32-1065. Consult NLSI for futher assistance.

3.0 GROUNDING.

Lightning will follow all conductors to ground (earth) according to their respective impedances. The grounding Earth Electrode System (EES) must address low earth impedance as well as low resistance. A considerable part of lightning's current responds horizontally when striking the ground: perhaps less than 15% of it penetrates the earth. As a result, low resistance values are less important that grounding volumetric efficiencies as is described in NFPA-780. This is a major reason why the integration of a rebar-reinforced concrete foundation as primary EES (also known as a Ufer ground) is an important design criteria.

Equipotential grounding is mandatory. It is achieved when all grounded equipments are referenced to a common earth potential. Generally this would include electrical grounds, lightning grounds, single point grounds, multi-point grounds, single reference grounds, computer grounds, etc. etc. Where the instance of a "clean (isolated) ground" is required, a "chispa" or gas tube arrestor can be installed for this purpose. Earth loops and consequential differential rise times (GPR) can be avoided by attention to equi-potential grounding and bonding of all structures on the property. The grounding system should be designed to reduce AC impedance and DC resistance. The use of buried bare counterpoise or radial wire conductors can lower impedance, as they allow lightning energy to diverge as buried conductors shares voltage gradients. Bare wire counterpoise (ring) designs connected around structures are more useful than ground rods. Proper use of concrete footings and foundations (Ufer grounds) will increase electrode volume. Where high resistance soils or poor moisture content or absence of salts or freezing temperatures are present the treatment of soils with carbon, Coke Breeze, conductive cements, natural salts or other low resistance additives may be useful. These should be deployed on a case-by-case basis where lowering grounding impedances are difficult and/or expensive by traditional means. Consult NLSI for futher assistance.

4.0 SURGE PROTECTION.

According to IEEE STD-1100 the principle sources of electrical power transient disruption are sub-station switching activities and lightning. The approximate ratio of faults from these upsets is about 10:1 depending upon geographic location. Ordinary circuit breakers, fuses and UPSs are not capable of protection from lightning-induced transients. By definition, "arrestors" are employed for protection on high voltage circuits such as 4160 VAC and above. Surge Protection Devices (SPD/TVSS) are suggested by NEC to be installed at 480VAC circuits (Primary Panels) and other lower voltage circuits such as 120/208240 VAC (Secondary Panels) as well as all communications/data/signal circuits including AC, DC and RF power and coaxial/twin lead/Cat 5/Cat 6/RG-58 and other antenna signal circuits. A staged or hybrid or layered defense strategy is recommended. By example, an 800 MHZ Radio Network should have SPDs on the AC circuit as well as the antenna circuit. Other examples would include PLC SPD protection on MCCs, SCADA circuits, the lightning detection system, security areas such as FLIR and CCTV, etc. etc.

A comprehensive analysis of electrical schematics is necessary to identify "critical" operations where SPDs will be required. Begin with identification of locations where SPDs should be considered. We recommend the following protection levels for cases of direct and indirect lightning attacks:

Primary (Main) Panels	Minimum 250kA
Secondary (Branch) Panels	Minimum 125kA

Specifications for SPDs, as well as installation practices and recommended SPD vendors are described in the NLSI Red Book "Lightning Protection for Engineers". Suggested vendors for DIN-rail mounted SPDs included Dehn, Phoenix-Contact and Siemens. For electronic communications and other RF signal circuits, vendors such as Polyphaser, Citel and Nextek are suggested.

Generally NLSI recommends a comprehensive installation of SPDs, including but not limited to: AC power main panel; all relevant secondary distribution panels; all valuable plug-in devices such as process control instrumentation, computers, printers, fire alarms, data recording & SCADA equipment, etc.; all incoming and outgoing data and RF signal lines (modem, LAN, communications, antenna, etc.); and all electrical devices which serve other assets such as water pumps, remote security alarms, CCTV cameras, high mast lighting, etc. This is not a complete list and each site requires different solutions. Consult NLSI for futher assistance.

5.0 Conclusion. Lightning protection is dependant in part upon attention to detail. ATs (lightning rods) have secondary merit in the survivability of sensitive electrical and electronic equipments in today's complex operations. By emphasis on topological shielding – bonding, grounding and surge protection -- the engineer can meet or exceed requirements in Codes & Standards, in safety, in engineering and similtaneously minimize liability issues.

6.0 References.

6.1 NFPA-780: 2014, Installation of Lightning Protection Systems, NFPA Quincy MA

6.2 NFPA-70:2014, National Electrical Code, NFPA, Quincy MA

6.3 IEEE 1100: 2005, Powering and Grounding Electronic Equipment, IEEE, NY NY

6.4 IEEE 142: 2007, Grounding of ndustrial and Commercial Power Systems, IEEE NY NY

6.5 Motorola R-56: 2000, Standards and Guidelines for Communications Sites, Motorola Corp., Schaumbery IL

6.6 IEC 62305: 2005, Protection Against Lightning, IEC, Geneva Switzerland

6.7 U S Air Force AFI 32-1065 Supplement 1: 2003, Grounding Systems, US Dept of Air Force, Washington DC

6.9 NASA KSC STD E-0012F: 2013, Facility Grounding and Lightning Protection, Joihn F. Kennedy Space Center FL

6.10 Normas NMX J-NMX-549-ANCE-2005: 2005, Subcomite de Pararayos, Asociacion de Normalizacion y Certificacion (IIE), Guadalajara Mexico