LightningMaster Corporation

# Lightning Protection: A Three Pronged Attack

**Integrated Three-Step System:**
Based upon our experience, we have developed an integrated systems-approach to environment optimization which may be tailored to any type of facility or operation. The Lightning Master® approach consists of three steps:

- **Bonding and Grounding**
- **Transient Voltage Surge Suppression**
- **Structural Lightning Protection**

As you read through the various sections, you will notice that it is based upon the three step program. To implement our solutions-based approach, Lightning Master® personnel will conduct a survey of your facility, provide you with a written report of our findings, design and recommend the optimum system solution, and, should you prefer the turnkey approach, provide and install the system we recommend.

We can also help you write specifications to assure effective and uniform practices at and between your facilities. Whatever you need, we can provide in a prompt, cost-effective package.

After you read through our information, please call us with your specific questions regarding our approach and how we would apply it to your type of application. We will be happy to discuss any aspect of our program, and, if you would like, meet with you at your convenience for an in-person presentation.

2100-A Palmetto St., Clearwater, FL 33765
800-749-6800
lightningmaster.com

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## Bonding & Grounding

Bonding is simply a matter of taking all of the electrical and metallic masses in a facility and connecting them with conductors, bringing them to the same electrical potential. The primary reason for bonding is personnel safety, so someone touching two pieces of equipment at the same time does not receive a shock by becoming the path of equalization if the two pieces of equipment happen to be at different potentials.

For the same reason bonding protects people, it also protects equipment, by reducing current flow on power and data conductors between pieces of equipment at different potentials.

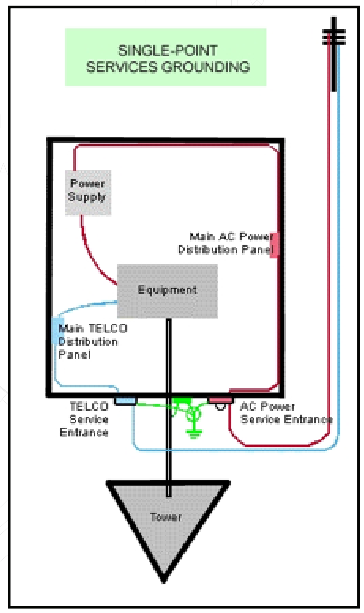
Grounding is a matter of bringing the bonded equipment mass to the potential of the surface of the earth which it occupies. Again, the primary reason is personnel safety, and the secondary reason is equipment protection. When it comes to grounding, we need to consider two types of grounding: low-impedance grounding of structures, and single-point ground potential referencing for services and equipment.

## Low-Impedance Structural Grounding

A structure is anything that is likely to be struck by lightning. Multiple low-impedance paths to the grounding system transfer lightning energy off of the structure and into ground as quickly as possible. Since lightning is very high frequency, low-impedance, the key to grounding is not just low-resistance, but the paths themselves. The higher the impedance the lightning energy "sees", the greater the voltage increases. The higher the voltages, the more likely the energy will arc or take unwanted paths to ground.

## Single-Point Services and Equipment Ground Potential Referencing

Why is it that direct lightning strikes at two similar facilities can leave one undamaged and the other virtually destroyed?




Among all the variables involved in system design, we have found the single most important factor in effective lightning protection to be not simply bonding and grounding of equipment and services, but proper connection of the services and equipment bonding sub-system to the grounding system.

A change in potential per se, does not damage equipment. It is a difference in potential across your equipment causing current flow through your equipment which causes damage. If the potential of the entire system changes at the same time and rate, and the equipment does not have any other source of ground potential reference, there is no current flow and no damage occurs.

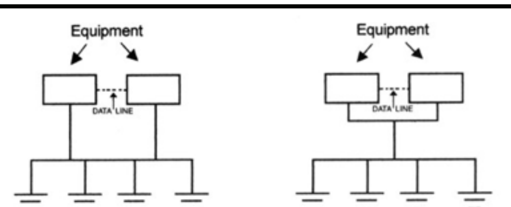
Current divides and takes all paths. The proportion of the current flowing on any one path is proportional to the surge impedance of that path relative to the total surge impedance of all paths. Even if heavy duty bonding straps are provided between grounds as the primary intended path of equalization, some of the current flow will be through unintended paths; through other conductors and equipment.

Therefore, it is critical to bring all services and equipment grounds within a facility to the same potential before they connect to the grounding system, eliminating the possibility of current flow.

In a typical facility, we must be concerned with several different ground potentials.

The first set of ground potentials is associated with the services to the site, i.e., AC power, TELCO, data and RF transmission lines from antennae. If a piece of equipment is connected to both a data line and to a power supply, and there is a difference in ground potentials between those two service grounds, that difference in potential can equalize within the equipment, causing damage or accelerated wear.

The second set of potentials is associated with the various electrical and electronic equipment chassis grounds. If two pieces of equipment are communicating with one another through a data line, and if there is a difference in potential between the two pieces of equipment, that potential can equalize through the data lines within one or both of the pieces of equipment, (see illustration below).




Mutiple-point ground potential referencing (can cause current flow through equipment)

Single-point ground potential referencing (prevents current flow through equipment)

When we refer to the facility equipment, it is important to note that we are referring only to electrical or electronic equipment, not door frames, air conditioning ducting, miscellaneous masses of inductance, etc.

To perhaps oversimplify the concept, envision an imaginary plane at or just below the floor level of the facility. All of the site equipment and services should be appropriately bonded together above this plane, and an appropriate grounding system established below this plane. All services and equipment grounds should pass through one and only one hole through that plane. Therefore, all equipment within the site will be at the ground potential of that single-point. This concept is commonly referred to as "single point grounding", or, more accurately, "single point ground potential referencing".

## Transient Voltage Surge Suppression

The energy and raw power contained in a lightning strike are truly awesome. It is easy to imagine the havoc which a direct strike to your facility can cause. However, the majority of electronics damage is not caused by direct lightning strikes, but is rather the result of transient voltage and current surges induced on power, telecommunications or RF transmission lines by the strong electromagnetic fields created during a lightning strike, and by more mundane causes such as power company switching, nearby heavy loads, traffic accidents involving utility poles, etc.

These surges can propagate for miles on metallic conductors, ending up at your facility service entrances retaining sufficient energy to damage or destroy electronic equipment. If you do not take steps to stop them, power surges can enter your facility and damage or upset your equipment. These transients were not so much of a problem in the days of vacuum tubes which operated on high internal voltages. However, with the introduction of microprocessors which operate on very low internal voltages, they have become a very real problem.

Every day, transients of all types are causing wear and tear on your equipment. With the move toward faster digital equipment, the problem will become more noticeable and expensive. The faster the electronic device, the more susceptible it is to transients. It is not possible to make electricity travel faster. Therefore, if you want to make a device operate faster, the distance which the electricity travels must be reduced. When you reduce the distance, the arc-over voltage becomes lower. Therefore, the device is more susceptible to a transient. So there is a need for some type of device to stop power surges before they enter your facility, and to stop internally generated transients before they are distributed to your equipment.

A transient voltage surge suppression (TVSS) device simply limits the voltage to a value slightly above the nominal operating value of the system to allow normal operations, yet below a value which will allow damage to connected equipment. Lightning Master® offers a full line of transient voltage surge suppression (TVSS) equipment for all types of services designed to provide the most efficient and cost-effective protection possible.

## All-Mode Protection

Here are two types of transients: common mode and transverse mode.

To illustrate, let us examine the simplest type of system, a two wire 120 volt circuit. One wire, the line wire, is nominally at 120 volts compared to the electronic device. The other wire, the neutral or return wire, is nominally at zero volts compared to the equipment. As long as the difference in voltage is 120 volts, the electronic device is happy.

However, there are two types of transients which may appear on these wires. The first type is a transient on one wire. Say the line wire suddenly momentarily jumps from 120 volts to 2,120 volts with a 2,000 volt transient. The electronic device is straddling the two wires looking for 120 volts. If it suddenly sees 2,120 volts, it may sustain damage.

The second type is a transient on both wires. With the same 2,000 volt transient, the potential, or voltage, on the line wire jumps to 2,120 volts, and the potential of the neutral wire jumps to 2,000 volts relative to the electronic device. In this case, the excess voltage may cause arcing between the electronic device and the chassis in which it is contained, which nominally remained at zero volts.

Therefore, in a two wire system, two modes, or legs, of surge suppression are required; one mode between the line and neutral wires and a second mode between the neutral wire and the equipment chassis or ground. The same principle applies to multiple wire systems; the more wires, the more modes of surge suppression required.

## AC Power

High voltage, high amperage transients may enter your facility on the AC power service. Therefore, it is important to employ a robust TVSS device at your AC power service entrance. Lightning Master® offers the highest quality main panel devices to prevent transients from entering your facility from the outside. However, power company studies have revealed that the majority of the transients seen by your equipment do not come from outside your facility, but rather are generated inside your facility by motors and other loads.

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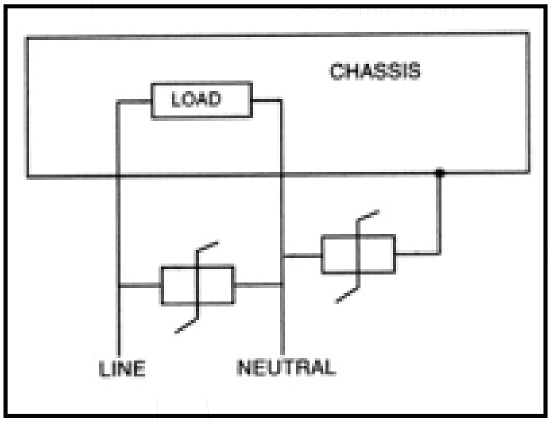
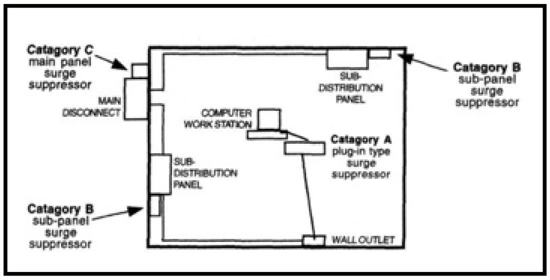



Lightning Master® also offers a full line of sub-panel TVSS devices to limit the "sharing" of internally generated transients. These devices are installed on your sub-panels, so that when a transient originating on one circuit travels back to its sub distribution panel, the TVSS device limits it before it can be redistributed onto other circuits within the panel, including circuits feeding your sensitive equipment. This approach of installing multiple TVSS devices in series is called "staged protection", and is particularly effective in limiting damage from both externally and internally generated transients.

**Telephone and Data**

Telephone and data line transients may be high voltage, but are usually relatively low amperage, the current being ultimately limited by the wire size. However, telephone and data devices tend to be very susceptible to damage or interruptions caused by transients.

Therefore, high speed, tight clamping value




TVSS devices should be employed at your telephone and data service entrances. Lightning Master® offers a full line of TELCO and DATA TVSS devices for all applications, including POTS lines, T-1, and computer networks.

**RF Transmission Line**

Since RF transmission lines are connected to antennas which are often the highest structure in the area, they are capable of delivering high voltage, high amperage transients to your facility. Since DC power may be fed up a transmission line to power equipment near the antenna, TVSS devices for this application may have to be designed to allow DC power to pass unobstructed. Conventional devices employing internal RF coupling and gas tubes wired at a right angle to the main path through to the equipment are no longer capable of protecting modern equipment.

State-of-the-art devices, devices in which the low impedance path leads to ground, and the higher impedance path leads to the equipment, need to be employed to secure maximum protection. Therefore, Lightning Master® offers a full line of gas tube and one-quarter wavelength shunts.

Installation considerations: When planning system layout, it is important to install surge suppressors to achieve maximum performance while avoiding situations which could compromise their performance.

During installation, avoid routing unprotected and ground wires adjacent and parallel to protected wires, where transients can be inductively coupled from the unprotected and ground wires onto the protected wires downstream of the surge suppressor. This also applies to routing protected wires from one type of service, particularly a low-voltage service such as telephone or data, adjacent

*We wrote the book on Static Solutions and Lightning Protection.*

to the unprotected or ground conductors of another service, such as AC power or radio frequency (RF) coaxial cables. A transient on either the unprotected or ground conductors of one service may be inductively coupled onto the protected conductors of the other service. Often we will see surge suppression elements installed directly on the circuit board they are intended to protect. This is less than optimum placement, as once the transient is on the board, it is generally too late to limit its propagation across the board.

Avoid locating a surge suppressor inside a metal enclosure containing the protected equipment. When a surge suppression element reacts to a transient, it emits an electromagnetic pulse (EMP). If the surge suppressor is located within the same metallic enclosure as the protected equipment, the Faraday cage effect of that enclosure will tend to contain the emitted EMP within the enclosure where it may be inductively coupled onto conductors within the protected equipment. Therefore, the surge suppressor should be located outside the enclosure containing the protected equipment, using the Faraday cage effect to keep the EMP out of the enclosure.

Long conductors and bends in the conductors between a parallel TVSS device, such as an AC power surge suppressor, and the load it protects can dramatically affect surge suppressor performance. At a 3 kA, 8 X 20 microsecond pulse (IEEE standard pulse), each foot of conductor length can produce in an increase in clamping voltage of 150 to 200 volts. Therefore, in the case of a surge suppressor connected to a load with three feet of conductor, the inductive reactance of the conductor can increase the clamping voltage of the surge suppressor by 900 to 1200 volts (three feet in each direction between the surge suppressor and the load). Also, the travel time along the longer conductors can delay surge suppressor response time.

To address these and other problems, Lightning Master® developed the services vestibule concept. As the name implies, a services vestibule is a separate enclosure through which all service conductors (AC power, telephone, data, RF, etc.) enter a site or remote equipment cabinet. Each service is grounded to a main ground bus within this vestibule. The main ground bus is grounded to an appropriate site ground, and bonded to any structural lightning protection system. A surge suppressor is installed on each service conductor, and grounded to the main bus. No conductor enters the site or equipment cabinet until it has been grounded and surge suppressed in this separate, adjacent vestibule. This approach keeps all the "bad" things, such as grounding, surge suppression, and EMP, outside of the site or remote equipment cabinet. Only grounded, protected conductors are allowed inside.

Lightning Master® will be pleased to assist you with your system layout to eliminate problems and to optimize surge suppressor performance.

## Structural Lightning Protection

The third step in securing effective lightning protection is generally referred to as structural lightning protection. This term describes what is most readily recognized as the traditional lightning rod (air terminal) system, with its associated bonding and grounding systems.

It is important to note that the purpose of a lightning rod system is to keep the protected structure from burning down. That is why lightning rod systems are covered under National Fire Protection Association standards. That was fine back in the days of barns filled with hay and horses. Lightning would strike the lightning rod on the barn and be conveyed to ground. The barn would not burn down, and everyone would be happy, particularly the horses.

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However, we have now taken the hay and horses out of the barn and installed computers. Lightning now strikes the structure, and the energy is conveyed to ground. The barn does not burn down, but now, none of the computers in the barn work. So everyone is not happy.

Since we cannot, with currently available technology, influence the formation of cloud charge or of stepped-leaders, if we want to influence the attachment of cloud-to-ground lightning, we must influence the formation of ground charge and of streamers. Hence, the introduction of streamer-influencing technology.

A good illustration of the general principle is found in the debate between the relative merits of a sharp lightning rod versus a blunt lightning rod. Please refer to the lightning propagation section (next) of these white papers for a review of lightning strike mechanism. Assume we have a sharp rod and a blunt rod side-by-side with the axis between them perpendicular to, and directly facing, an oncoming electrical storm. As the ground charge reaches the two rods, the potential rises on both. The sharp rod will tend to break down into corona under a relatively low potential, leaking off some of the ground potential to the atmosphere. The blunt rod will hold its charge, with ions accumulating on the blunt end.

As the ground potential builds, the corona builds around the sharp rod, while the blunt rod still tends to retain its charge. When the ground potential becomes very high, as when stepped leaders are on their way down from the cloud and there is going to be a strike in the immediate vicinity, the corona will build in density and elevation around the pointed rod. When the blunt rod finally breaks down, it breaks down catastrophically, and the accumulated charge jumps off of the blunt rod in a streamer extending well upward toward the stepped leaders.

Since the object on the ground that throws off the best streamer is the one most likely to be struck, the blunt rod is more likely to trigger a strike than is the sharp rod. Streamer-influencing technology uses this principle to influence strike termination likelihood. If you want to direct lightning to a preferred attachment point, do so with an early streamer emitting (ESE) air terminal. If you want to discourage lightning from attaching to a protected structure, use streamer-delaying air terminals. If you merely want to intercept a close proximity lightning strike, use a conventional lightning rod system. Lightning Master Corporation offers all three technologies, based upon the requirements of our customers.

## About Lightning Master Corporation

Established in 1984, Lightning Master® is a global, full service, static solutions, lightning and surge protection manufacturing company. We serve a wide range of customers including oil, gas, chemical and other industrial facilities. Our complete line of products, systems and consulting services are backed by our worldwide customer service. Our track record of success in the Americas, Asia, Africa, Europe and the Middle East has established LMC as a global authority on lightning and static protection.