White Paper

LIGHTNING AND SURGE PROTECTION

Application Note: Lightning and Surge Protection

Because wireless systems are typically located out of doors and have components located on towers and tall buildings, they are especially susceptible to damage from lightning. Therefore, it is important that a lightning protection system be designed and implemented at the same time the wireless system is being designed and implemented. Doing so will result in less down time and lower liability for people and property.

Lightning Threat and Protection Concepts

The selected lightning protection system must be designed and implemented such that no form of lightning related destructive, disruptive, or reliability impairment phenomena can penetrate or enter the protected system. A direct strike can cause physical damage and secondary effects of lightning can and will damage electrical and electronic systems within the area under protection and can cause fires.

Direct Strike Lightning Threat

Direct lightning strikes present several types of hazards in addition to the direct strike including:

- The direct strikes - physical damage
- Secondary arcing phenomenon – fire or explosion
- Induced transients – electrical damage
- Power line surges – electrical damage
- Electromagnetic pulse – electrical damage

It should be noted that lightning is a probabilistic function and as such, the number of lightning strikes terminating within an area may vary drastically from year to year, or over short periods of a few years. With a direct strike to or near any area, there are a possible series of secondary effects that can be expected. These are described within the subsequent paragraphs, and account for many lightning related losses.

Secondary Effects

The direct strike influences the immediate area of the termination. The secondary effects can influence areas as large as several square kilometers. In summary these function as follows:

- Earth Current Induced Transients

The charge within the storm cell induces an equal and opposite charge on the earth beneath it. Everything takes on the charge because the charging rate is slow. When a strike terminates, all of the charge travels to the termination point within about 20 microseconds. Any conductors buried within the surrounding earth will act as the preferred conductors for this charge, thereby inducing transients within those conductors. Shielding only changes the character of the induced transient; therefore any component connected to those wires experience high voltage transients.

- Secondary Arcing and the Bound Charge

With reference to the foregoing (Earth Current Induced Transients), conductors that are isolated from earth or largely insulated materials such as flammables will take on a charge. The charge is unable to be released within the strike neutralization period (less than 100 microseconds) and is “bound” on the material as a result. When the surroundings are neutralized, the difference of potential between them results in an arc, called the “secondary arc”. This is a major cause of flammables related fires.

- Atmospheric Induced Transients

The varying electrostatic field between the storm cell and earth causes atmospheric transients. The varying electric field induces high voltage transients on any wires immersed in that field. The higher the elevation of these wires, the higher the induced voltage sometimes referred to as “Electrostatic Pulse”.

- The Electromagnetic Pulse (EMP)

Lightning creates a large electromagnetic pulse. The EMP within that magnetic field will induce voltages on any nearby conductors. The di/dt can reach up to 500 kV/micro-second. The induced voltages can be in the millions of volts, but low energy.

Strike Protection Concepts

The lightning system protection concept must provide a cost-effective way of preventing fires, physical damage, system downtime, or other losses. To accomplish this, the lightning protection system must isolate the vulnerable equipment in an area against all primary and secondary forms of lightning related influences. Conceptually, there are three lightning protection concepts that can be used to provide a lightning protection system.

- A Strike Prevention System

A lightning strike prevention system is designed to eliminate direct lightning strikes from terminating in the area under protection. No other provisions are provided for the secondary effects of the lightning strike. This type of protection scheme assumes that the area or site is physically isolated, and that no other electrical pathways exist that could transmit or induce transients into the electrical and electronic systems installed in the area.

- The Application of Circuit Protection Technology

The second protection concept requires the installation of electrical surge protection devices on all electrical interfaces. This requires the placement of 100% effective surge or transient protection modules at every potentially vulnerable electrical and electronic interface with what could be considered the atmospheric world. Every telephone line and every power source that is potentially exposed must have a protector. This concept if used by itself would not address the potential risk of direct strikes that may cause physical damage or possible fires caused by secondary arcs in the area under protection.

- The Comprehensive Closed System Concept

The third method of protection employs the best of the foregoing concepts, a lightning strike prevention system and the application of circuit protection on all interfaces into or out of the area under protection. This method involves the logical use of a strike prevention system for critical areas and the use of circuit protectors that isolate all of the electrical and electronic systems used within the area under protection.

Direct Strike Prevention

Protection of equipment against direct strikes infers dealing directly with the strike itself, or with the mechanism that creates the strike. If the lightning protection concept is to deal with the strike, it must be capable of handling all of the parameters without permitting any of the potentially harmful side effects of the lightning strike. If the lightning protection system deals with the mechanism that creates the strike, it eliminates the strike and also eliminates the secondary effects.

In practice, preventing a lightning strike is very difficult and requires the use of specialized equipment and expertise that may exceed the means of the average ISP.

Power Protection Concepts

The electrical power supply circuits that feed the site and other components are vulnerable to surges coming in on the primary power line from the public utility. To provide safe protection and prevent reduced reliability from all types of electrical disturbances, the selected protection equipment must possess the capability of eliminating the following surge parameters:

- Peak currents of up to 500,000 amperes at the service entrance.
- Surge voltage rise times of 50 nanoseconds.
- Surge energy levels of up to 50,000 joules where local utility is used.
- Surge energy levels of up to 2,500 joules where location generation is used.

In addition to the foregoing, it is necessary to devise a protection system that will preserve the intended reliability of the customer's equipment. This imposes a much more significant constraint on the protection systems design. The peak allowable voltages under surge conditions must be limited to about 1.5 times the peak voltage for at least 90 percent of the potential peak surge currents.

A series-hybrid surge suppressor usually offers higher energy handling capabilities and tighter voltage clamps than comparable parallel designs. Also, the series design results in faster reaction times. This satisfies the high energy handling requirement and results in no loss due to lightning related surges. However, this same type of performance can be achieved through the use of what is called a "Series-Hybrid Equivalent" (SHE). SHE performance is achievable in large facilities by "staging" the protection. A Class C protector is used at the electrical service entrance and a Class B protector is installed at the electronic systems power distribution. The exact module required is a function of the location risk.

Low Voltage Protection Concepts

The protection of low voltage devices from transients is becoming one of the most important aspects of the lightning protection system. With the advent of advanced digital and analog process control systems, greater attention to the design of the transient circuit protection system must be made. Protective options are many, ranging from parallel to the series devices and from low-energy semiconductor to high-energy gas tubes or series-hybrid units. Again, the series-hybrid circuits are strongly recommended since these are the only 100% effective forms of protection of reliability for sensitive low voltage circuits.

To be 100% effective, any data line protection must be able to handle the following transient parameters without failure:

- Peak surge current up to 10,000 amperes
- Surge rise time of 50 nanoseconds
- Energy Levels up to 500 joules

This type of protection system will prevent the passage of transients. Other parameters such as clamping voltage, operating frequency, band-width and current flow vary with the application. Each type must be evaluated against the foregoing or a related risk must be accepted. Again, the specific data line protection characteristics will be determined by the specific application and equipment requirements.

Grounding Considerations

Historically, grounding has been used to satisfy two separate functions:

- Establishing an electrical connection to earth, thus the British term Earthing.
- Establishing a common reference point for all voltage related to a given system.

These objectives can be satisfied individually within a piece of electrical equipment by using the chassis as the reference, usually called chassis ground. Conversely, an earthing electrode can be any form of conductor submerged in the earth by any means. Earthing electrode effectiveness, resistance, and surge impedance depend on at least these factors:

- Soil Resistivity
- The Application Requirement
- How the Grounding System is to be used
- The number of earth interfaces that are to be provided for one facility
- The grounding resistance or surge impedance actually achieved

Of the foregoing, two factors deserve significant thought: surge impedance and the number of earth interfaces.

The Surge Impedance Factor

This factor has been a neglected factor in considering how the grounding system should be designed, or how it should respond in use. In fact, most grounding applications involve the response to transient phenomena such as lightning, RFI, and other communications systems, or even "*ground faults*" caused when a phase wire first shorts to earth. To provide a low surge impedance-to-earth interface, the requirements are much different than that for low DC resistance.

Multiple Earth Interface

Multiple grounds for a single facility are a fallacy that has grown out of the computer industry. As a result, lightning has created significant losses within communications and control systems and resulted in various engineering disciples suggesting changes in the earthing criteria. The common response is that lightning is an *earthing problem*, when in fact that is not a true premise. Lightning should be thought of as another form of transient along with Radio Frequency Interference (RFI) which must be filtered or neutralized. It is a high voltage and high-energy transient that can create multiple forms of secondary transients as discussed within this report.

Given the above premise, the protection system must be designed to deal with lightning and secondary effects. It is an earthing problem only in that these transients appear *between* the System components and earth. Since that is true, these transient phenomena must be provided a low impedance path around that to be protected.

Earth is simply an electrical reference point for the system. *Every* component must be referenced to the same point *directly*. Otherwise, voltage differences will appear between these earthing points. These voltages will also be present between the system components that are connected to these different earths. Connecting two or more separate grounds at some remote point does not eliminate this risk. Lightning and its secondary effects is a transient, therefore, the surge impedance between these connections becomes the significant factor. Use of interconnecting chokes only compounds the problem. A strike to one of the unit components initiates a current flow through the earth surrounding that component and unit. That current flow develops voltage differences between the earthing points (earth is a resistor). That voltage difference will be present within the system as a high voltage, low energy transient and an arc will be present.

Lightning protection cannot be accomplished through earthing alone since earth is a system reference point. Every system should use the same reference to prevent voltage differences. The multiple-earthing concept has no foundation in physics; in fact the opposite is true. Existing standards do not deal with contemporary system problems. What may have worked as little as five years ago is often inadequate or a problem source today.

The only satisfactory solution is to use the *Common Point or Grounding Window* concept and to reference all parts of the system to that point and, in particular, all of the lightning protection components. In this concept, the lightning protection components limit the allowable voltages to be applied to a given piece of equipment to a safe and predetermined level. The end result is that the actual resistance to earth is irrelevant because the whole site (and everything on it) rises and falls together, maintaining a unified reference. The potentials (voltage) between components remain unchanged and the use of more than one earth interface (grounding) negates the unified reference.

Lightning Protection Summary

To summarize, the proposed lightning protection system includes the following key elements:

- Strike prevention if possible
- Transient Voltage Surge Suppression (TVSS) for electrical power systems

- Transient Protection for vulnerable data lines
- Ground Charge Collector (GCC)

The protection system will provide the area improved protection against: direct lightning strikes, and the secondary effects of lightning strikes.

WaveBolt

Based the function of the WaveBolt system and its application in the field protection can be provided by appropriate TVSS equipment and proper grounding of the equipment and the TVSS providing protection. Cirronet provides TVSS for both data lines and coaxial lines for both the Access Point and Subscriber units.

The foregoing explanation of low voltage protection requirements is the recommended minimum standard for the protection of the WaveBolt system. TVSS should be applied wherever there is risk of a lightning strike. These protection units should be grounded with the shortest lead length ground possible. (measurement in inches and not feet). Care should be taken to assure that the system, when applied is bonded well to the complete communications system. No difference in potential should exist between pieces of the equipment comprising the system. Care must be taken to assure that the shield of the cable is carefully tied to the ground with the lowest impedance method possible.

The ground for the facility where the system is collocated should comply with the recommendations in the body of the above Application Note. All ground wires should be adequately sized and make smooth downwardly (No sharp bends or 90 degree turns) connections. Once again the ground interface should be as short as possible. If ground conductors need physical protection, they should be placed only in PVC conduit.

Care should be taken to assure low impedance, and a low surge impedance earth interface.

If required the grounding should be augmented to achieve an earth interface impedance of 5 Ohms or less. This may be augmented with Chem-rods if required.

The AC feeds to the equipment should be protected by TVSS (transient voltage surge suppression) equipment as outlined in the Application Note above.

If located in a particularly bad (lightning prone- or previous lightning damage known) location, consideration should be made to apply DAS (Dissipation Array System) technology to the associated tower or structure.