

Experiences of Surge and Lightning Protection systems for ITS deployments.

Author: **BILL COOK**
Atlantic Scientific Corporation
4300 Fortune Place; Ste A
W. Melbourne, FL 32904, USA

Abstract – ITS equipment deployments on Interstate roads are particularly vulnerable to surge and lighting damages. This paper, discusses the surge coupling mechanism that causes the damage and experiences in the Southeast USA designing and installing protection systems.

INTRODUCTION

Surge protection devices (SPD's), along with international standards, have evolved over the past 50 years for applications in buildings and domestic dwellings. The past 10 years however have seen a remarkable increase in the presence of ITS equipment and towers across the world. These sites offer unique protection challenges and the simple application of techniques developed for commercial building will not provide the optimum protection.

The purpose of this paper is threefold:

- Firstly to discuss the coupling mechanism that causes damage and the unique characteristics of an ITS site compared to a commercial building or domestic dwelling.
- Secondly to evaluate risk scenarios.
- Thirdly to briefly review available protection techniques and suggest optimum solutions

Worse Case Lightning Strike

IEC 61312 gives 200,000A (10/350 μ s) as the statistically severe peak current level

discharged during a lightning strike. It is worthwhile noting that 99.5% of strikes will be less severe. Recent published results of lightning strike activity are very informative. Typical data currently available indicate the median current magnitude to be 35kA for a negative lightning strike, with less than 1% exceeding 120kA.

This data addresses the magnitude of the energy that can be expected from a direct lightning strike to an ITS pole, 40 –100 ft tall, installed in a remote area on the side of an interstate. We can call this the “worst case scenario”.

If surge protection systems are to be designed to survive a “worst case scenario” then there are a number of issues to be considered. We know that an effective protection scheme consists of both a grounding system and surge protection devices, (SPD's). These function together providing both a mechanism to divert surges to site ground via the SPD, (**Fig 1**) and to equalize potentials when site ground potential is elevated. (**Fig 2**). These are known

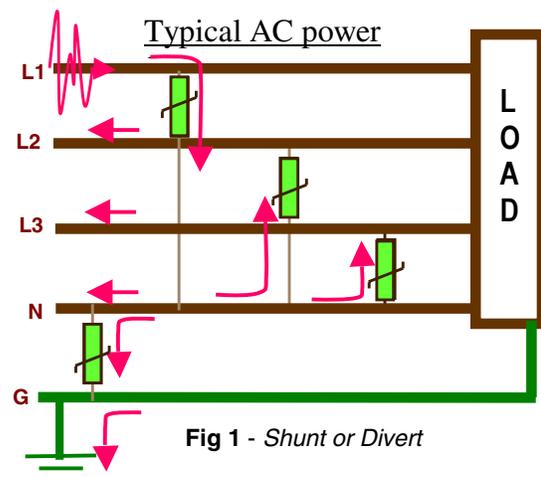
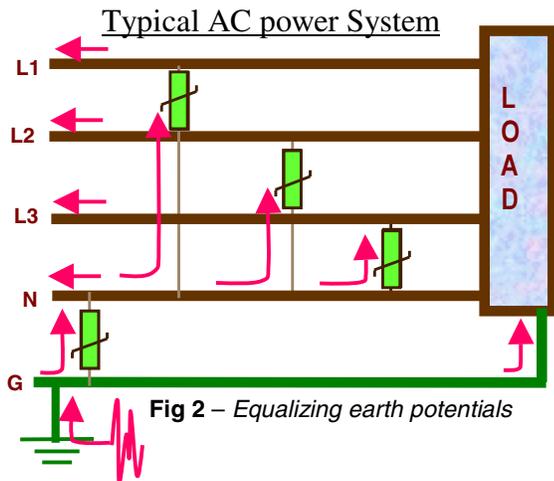


Fig 1 - Shunt or Divert

as the two functions of an SPD.

The IEC specification clearly shows that



the direct strike damage coupling, is energy attempting to flow to some connected lower earth potential that is at the end of any metallic circuit connected to the ITS site. This can be AC power, with earth reference at some distant transformer, or a camera on a pole, dislocated from the ITS cabinet and referenced to it's pole earth. This clearly demonstrates that a direct strike will “charge” the earth attachment point for some undefined time, likening the earth, at that point, to one side of a capacitor. The charged earth will attempt to “flash over” to lower potential earth's and cause

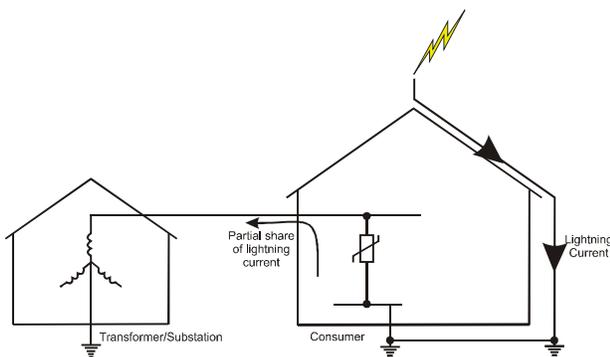


Fig 3 - Coupling Mechanism as defined in IEC 61312-3 for a typical domestic facility

damage en-route.

Understanding this mechanism and assuming that a site has a reasonable

grounding system, the question that designers of protection systems must answer is: “how much of that surge current will flow to earth and how much will stress surge protectors installed at the site being struck by lightning?” Understanding the coupling mechanism is key to understanding the level of threat.

The mechanism by which a partial share of the lightning current passes through the SPDs is shown in (Fig 3). IEC provides simple rules based on a residential application. Here the approximation is that 50% of the lightning current flows to ground. Since the substation transformer is separately earthed some distance away from the facility, the remaining 50% share of the lightning current flows through the SPDs and out toward the transformer. If the SPD fails, then the current will find a path via any connected electrical or electronic device. It is critical to see the similarity between figure 3 and a remote ITS site.

Earth potential elevations can be seen as the root cause of the majority of damage at a site. If we consider each of the mechanisms :

- Direct strike elevates site ground and every device that is connected to it. Flash-over's will occur to devices that have lower ground potentials. The risk is that even with an SPD on the AC power, it may not have enough surge current capacity to carry the current that is trying to leave the site. When it fails, the remaining energy will cause damage by finding an alternate route to equalize, often through the electronics. Providing an air terminal at a site to direct lightning strike current safely to ground is the correct engineering. However, an air terminal at a site or pole, will certainly create the scenario of an elevated earth. To install an air terminal, Franklin Rod, in the belief that it will prevent lightning damage, (cone of protection), is demonstrated to be flawed in these instances.
- Direct strikes or nearby strikes will elevate ground potential that will try to equalize over connected power, communications or data circuits that have a lower ground potential at their distant end.

- Sites where there is a cabinet that houses the electronics and a separate pole with the installed device, are classic earth potential risk sites. Many DMS, VDC & camera installations are prone to this damaging scenario.
- Instances where towers or devices are installed to “prevent” lightning strikes still leave a site, without comprehensive surge protection, exposed to elevated ground potential damage from a nearby lightning strike
- A surge delivered on a connected circuit, such as AC power, will activate it’s SPD thereby elevating ground potential. If the potential is high enough, flash-over’s will occur from ground referenced devices that do not have SPD’s but are connected to lower ground potentials such as communications or data circuits.

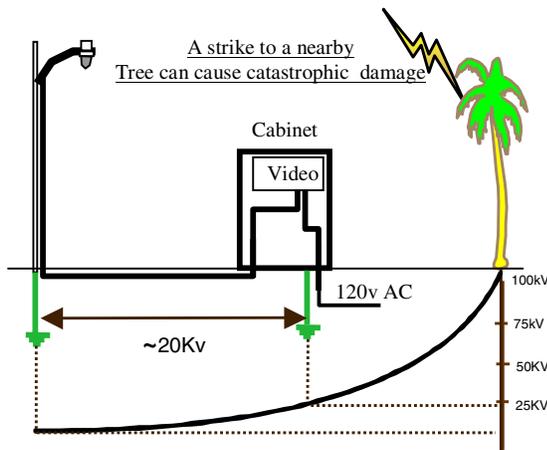


Fig 4 - direct strike coupling mechanism

Figure 4 clearly shows that even a nearby strike will elevate ground potential and cause surge currents to flow between the connected ends, to equalize. In such an example, either the camera or the video controller will have fatal damage. The distance between the pole and cabinet can be as small as 3 feet to sustain damage. This would depend on the surge energy, location of the strike and the impedance of the soil.

Dynamic Message Signs (DMS) are frequently installed with a cabinet, often containing the control electronics, located some small distance from the sign structure. This is generally done to facilitate the simple maintenance access to the electronics without effecting traffic flow. This configuration has even greater problems from elevated ground potentials and equalization.

The direct strike is rare, but when it happens

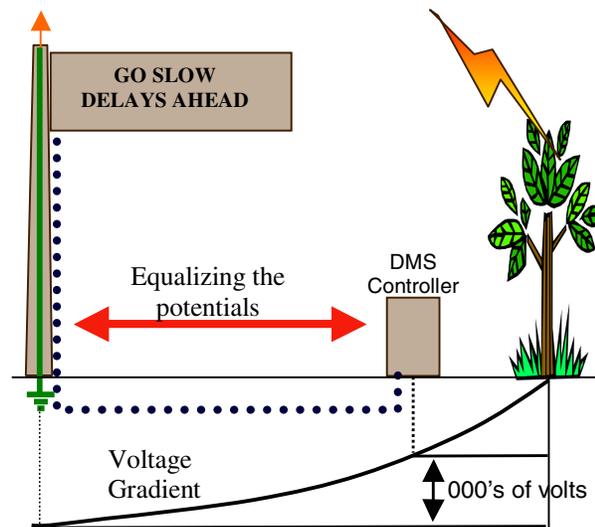


Fig 5: DMS with remote located control cabinet

the same mechanism applies. Energy will flash-over to any surface that has a lower potential. An example would be a camera on a pole. The pole gets struck at the air terminal and the energy is transported to ground at the base of the pole. The pole itself is energized to the level of the strike and will find a way to flash over to electronics in the camera or the connected cables. It is impractical to try to

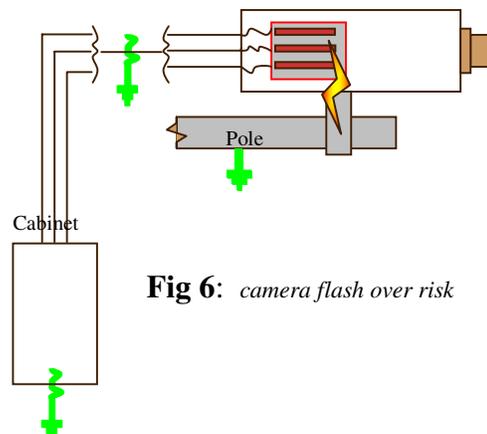


Fig 6: camera flash over risk

isolate the camera from the ground reference, the potential difference between pole and camera can be 100KV or more. (Fig 6). Earth or site ground is attached and referenced to the AC neutral at the “service entrance” point. All the DC systems in the electronics therefore have an indirect ground reference and it is common practice to connect safety ground to all metal parts. It is simpler and far more economical to install surge protection at the camera and in the cabinet, (Fig 7)

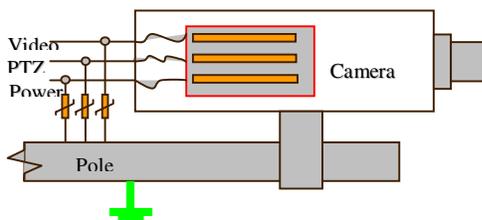


Fig 7: SPD's at the camera

ITS STRUCTURES & ELEVATED RISKS

Lightning earth attachment points are random, however, tall structures will effect this random distribution. Many scientific papers have been published discussing the relationship between the height of a tower or pole and the effected attractive radius to lightning. These indicate that the attractive radius (R), and it's associated attractive area $A = \pi R^2$ are primarily functions of the structure height H.

H (feet)	R (feet)	Effected Area (Ft ²)
75	~450	636,255
150	~750	1,767,375
300	~1,050	3,464,055
450	~1,200	4,524,480

Fig 8: The relationship between structure height (H) and Attractive Radius (Ra)

Intuitively the probability of frequent direct strikes to ITS sites on an interstate is significantly greater than a low building in city limits. In addition, a tall camera pole in the city, higher than the nearby structures, has a higher

probability of being struck than the nearby structures as it effects the random attachment of lightning in the area.

Installation of a device to reduce the risk of a lightning strike, may work at the site, but a strike to a nearby tree will elevate earth potential and still cause damage due to elevated earth potentials. There is no effective protection scheme without the use of surge protectors and a grounding system.

PROTECTION DESIGNS AND TECHNIQUES

Having detailed the various damage mechanisms, the question of appropriate systems design solutions is imperative.

There are a number of principles that have to be recognized:

- You cannot prevent the effects of surges at any site.
- The most frequent source of surge damage is due to elevated ground potentials equalizing.
- It is impossible to isolate a site from the effects of elevated ground potentials.
- Every metallic cable to and from a site must have surge protection.
- Both ends of any circuit or cable that interconnects equipment or cabinet, must have surge protection at both ends.
- The combination of a grounding system and surge protection is the only basis for a protection scheme.
- Surge protectors with adequate surge current capacity are required.

The solution is simple. Surge protectors must be installed on both ends of a circuit, to divert or shunt the current while equalizing the voltage.

It is important to select multi-stage hybrids that will ensure low “let-thru-voltages”, (LTV), irrespective of the magnitude of the surge current, when selecting surge protection devices (SPD's) for data, video and communications applications. These should be designed for the application and not a “general” solution. Individual components used in surge

protectors are non-linear in their performance. The higher the current in the surge, the higher the LTV. For this reason a multi-stage hybrid is used on low voltage circuits such as Video, RS data series and T-1 communications lines. The philosophy is relatively simple. A high current capacity “gas discharge tube” (GDT) is used as the primary device. The LTV is far too high but it’s output is inserted into a second device that controls the LTV to a lower level. The output of this in turn, is fed into a third device which controls the LTV to an even lower level, (Fig 9). This ensures a constant low LTV however care must be taken to install such devices “correctly” so that the unprotected outside world is input into the primary stage.

protection scheme that takes into consideration the unique issues that effect their risk to direct lightning strikes. These are often remote installations, located at roadside sites, with tall poles that effect random lightning. The Southeastern USA is particularly vulnerable to surges and lightning strikes where protection systems have been installed for some years and have proven to protect the infrastructure. It must be mentioned, that lightning is the most significant source of surges, however there are others which include utility switching surges and nearby defective electrical machinery. Designing a system to survive lightning will ensure the system will easily cope with other surge sources.

CONCLUSION

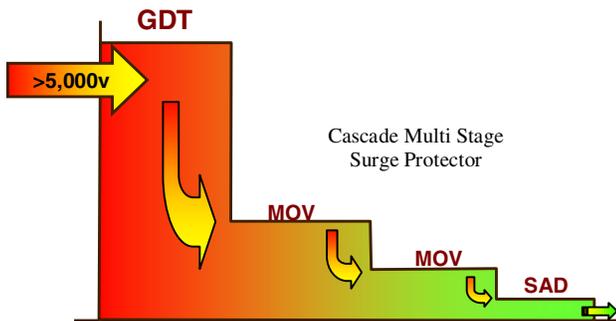


Fig 9 – Data, Video and Telco protectors

ITS is a critical component of all transportation systems meeting the demands of the growing traffic levels within our society. It is becoming dominated by sophisticated electronics with more and more complex systems being designed and added every year. A clear understanding of the damage mechanism from lightning and surges is essential in order to be able to design protection systems that will allow the equipment, installed on the road side, to be able to survive for decades. ITS sites require a carefully designed surge

For further information lease contact :-
Bill Cook
 Atlantic Scientific Corp
 Tel: 321-725-8000
 Email: bcook@atlanticscientific.com