Surge Protection & Earthing Systems for Traffic cameras

There has been a significant deployment of cameras in traffic applications in the recent years. They are used for vehicle detection at intersections (replacing loops) or as surveillance cameras to support ITS projects. In both cases there is a significant mortality rate of cameras, due in part, to lightning and electrical surges.

This paper discusses surge protection and earthing systems that have proven to minimize the damage from lightning related surges in high lightning activity areas of the USA.

The are a number of issues to review including the functions of a surge protector and the relationship between surge protection and earthing systems.

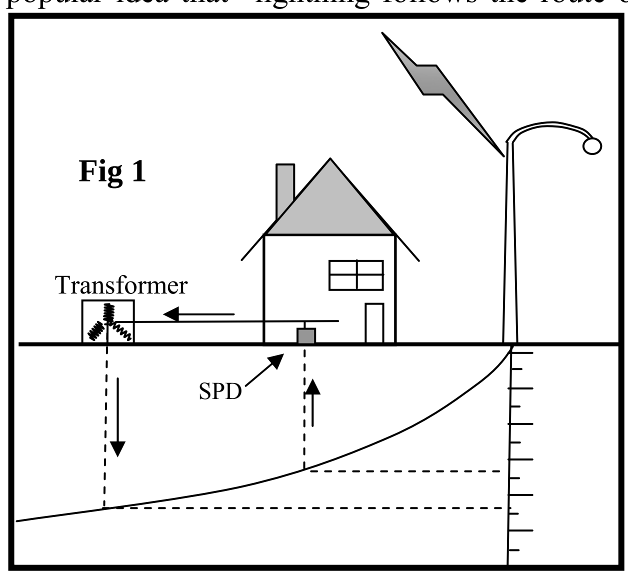
A surge protection device, (SPD), is simply a "voltage sensitive switch". When a surge voltage is detected, greater than it's MCOV (maximum continuous operating voltage), the SPD will transition from a high impedance (passive) device into a low impedance conductive device. When this happens, the SPD will "shunt" the current away from the equipment being protected and "equalize" the voltage or potentials on all connected lines. For example, an SPD connected between L-N and N-G will, in the event of a surge on the L, shunt the current of the surge to the N and elevate the N to the same potential as the L. This in turn will activate the N-G mode of the SPD and in turn equalize the potential on the G and also shunt current to ground. Some of the surge current will be diverted back to the utility transformer on the N, which is connected to a distant, probably lower, ground potential.

When the potential on the line returns to normal the SPD will return to a passive, high impedance state

"All of this happens in micro-seconds."

Equalizing the potential on all connected lines removes the risk of "flash-over's" which is a very frequent cause of damage. If the SPD fails, flash-over's and currents will be free to cause damage in the connected equipment.

Now consider that lightning hit something nearby, like the street light shown in Fig 1. The ground potential is elevated at the street light base, which can be 100's of kV. This energy does not dissipate instantly but charges the ground for some finite period of time. The charge is dissipating uniformly in all direction and will connect to the ground rod of a nearby house, which in turn, is connected to the E of the installed SPD. The N at the transformer is connected to ground at some distance away, which is at a lower relative potential than the house ground. Under these circumstances, the utility path to the transformer ground is a lower impedance path than the earth itself. This is the popular idea that "lightning follows the route of



least resistance".

If the surge protector fails, due to a surge current that exceeds it's capacity, then there will be "flash-over's" at the site between everything connected to the high potential ground and other

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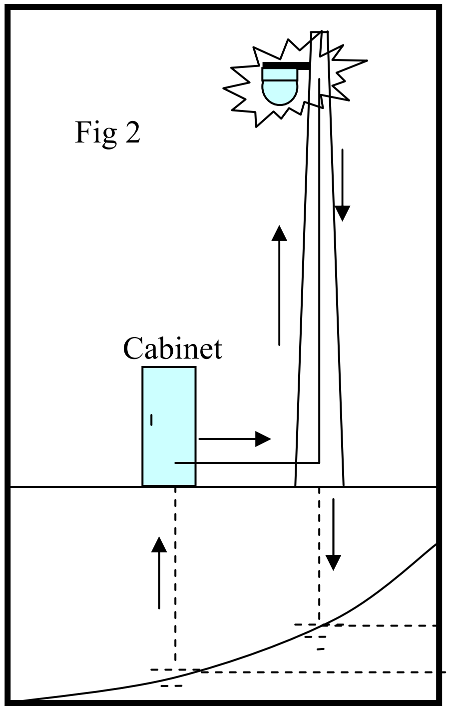
lower potential circuits. Flashover is the mechanism that causes most of lightning related damage and is often perceived as a direct hit to the premises.

This mechanism is key to the camera damages experienced on deployed ITS and traffic intersections. Earth potentials will equalize between two sites. (see Fig 2)

Lets first review the three mechanisms that cause surge related damage.

1. A surge on a connected line, such as Power, Telco or Data.
2. An induced surge, EMP from a nearby strike, into any one of these lines.
3. Elevated ground potential from a direct or nearby strike.



The Engineer, when reviewing any site installation or protection design, needs to consider the risk of each of these mechanisms and ensure that each has to be protected against.

For instance, if we consider a camera mounted on a pole with the electronics housed in a cabinet nearby, we can see that all three risks are present. Moving the electronics cabinet and mounting it on the pole will alleviate risk #3 but #1 & #2 are still present. A camera mounted on a small building inside the city's canyon of tall buildings will probably remove risk #2 but leave risks #1 & #3.

In all cases, surge protection must be installed. What is often neglected is the need to install surge protection at both ends of EVERY circuit on a site, not just the video connection but the 24Vac and PTZ data circuit as well. SPD's in the cabinet are referenced to the cabinet ground while SPD's on a pole will be referenced to the pole ground. This mechanism can be seen clearly in Fig 1 & 2. If SPD's are mounted in a cabinet with the camera electronics, but nothing at the camera end, then all the elevated ground potential will be sent to the camera, which will flash-over to the pole ground reference. Often burn marks can be seen on the metal clamp of failed cameras. This is the flash-over point for the energy to discharge to the pole and it's "different" potential.

The logistics of how to mount SPD's at the camera is relatively easy. There are three options.

1. When a "camera lowering "device is used, (for ITS applications), the surge protection is mounted in the termination box. (see Fig 3) This is lowered with the camera and often referred to as the weight. This is almost the perfect location for the camera SPD. It minimizes all three risks.
2. The addition of a box located close to the camera holding the SPD's. This is also a good solution although we have had comments that the addition on the box on the arm may cause camera movement in high winds, (see Fig 4).
3. Install the SPD's in the hand hold at the base of the pole. (see Fig 5). This is a convenient solution that minimize the risks from elevated earth potential and surges on connected lines, but has the "possibility" of induces surges

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Fig 5

from a nearby or direct strike to the pole and the generated. electro magnetic pulse (EMP)

In all cases, if the SPD's are DIN rail mounted REMEMBER to connect the DIN rail to the pole earth. If you do not connect the rail to the pole's earth reference you will achieve <u>nothing</u> and still incur failures.

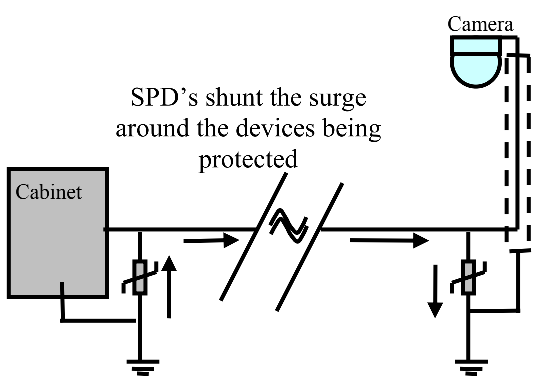
To further understand how this circuit design works we need to look at the function of the surge protectors in this application. (see Fig 6)

With an elevated ground potential, the highest potential will be closest to the lightning attachment point. The SPD's will transition into low impedance devices and conduct / shunt the surge around the devices being protected. The earth potential can be millions of volts in these circumstances. The wires between two points will be a lower impedance path than the earth resistivity. Most electrical and some electronic devices have dielectric strengths of typically 6,000 volts which will simply break down with such high potentials. In addition, sparks will flash across air gaps that can be as great as an inch. Flash-over's between printed circuit boards and frame or chassis of the mounting, is all too common. This phenomena depends on the fickle nature of the lightning. The amount of energy in a single strike is an infinite variable however there are some detailed scientific data bases that give us a clear indication. The median current in a lightning strike, from a data base of over 50 million events, is 35,000 amps. This amount of energy will flash-over very easily and break down normal dielectric. One of the potential sources of damage will be the risk of a surge being induced into the cables from a nearby strike flowing down the camera power cables back to the power distribution system in the

cabinet or damaging the 24v AC power supply used for the camera. A minor expense in SPD's will ensure a trouble free installation.

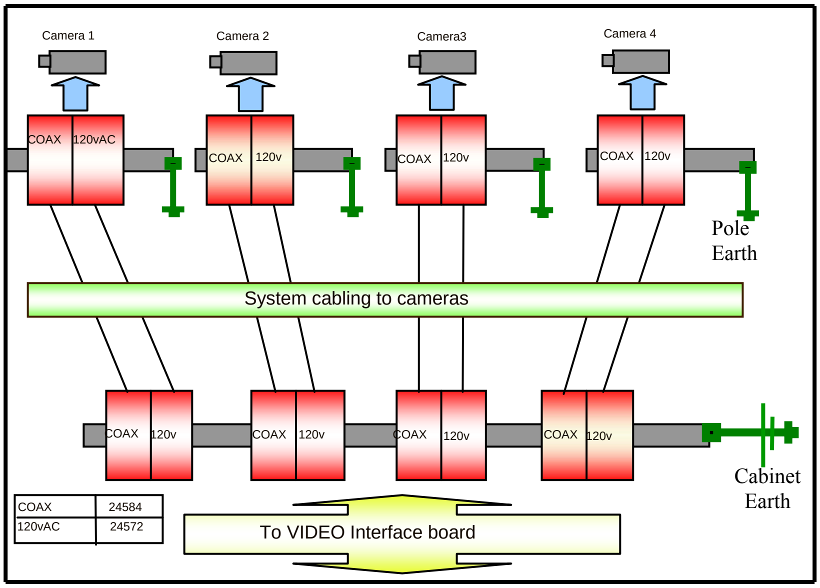
When we consider vehicle detection cameras at intersections, we have a more complex situation. The basic principles of the solution are the same, just more cameras. A typical installation has a control cabinet installed somewhere to the side of the pavement, out of the way of vehicles and pedestrians. The cameras are installed on mast arms or street lights, some distance from the cabinet. It is standard practice to drive a ground rod in at the base of the pole. In doing this we

Fig 6



ensure that the earth potentials will be different between poles and cabinet. It is good practice to interconnect the poles and cabinet earths through the conduits to reduce the impedance difference and by doing so, you will minimize the risks.

This design will also enhance and reduce the impedance of the complete intersection earth system. We know that the optimum spacing between earth rods is twice the length of the rods being used. This is generally impossible at an intersection; however interconnecting each poles earth rod can easily achieve 5Ω or less. You cannot rely on this interconnection to remove the risk of different ground impedances, the earth wire between poles have impedance and with time these connection will deteriorate.



An impedance of 5Ω between connected earths will still allow huge surges of energy to flow when equalizing potentials. Once a joint or connection begins to gain some impedance, a large surge equalization through this path will certainly vaporize the connection. This will never be detected unless they are checked regularly. Even if perfect (zero impedance), there will still be a sharing of energy between the direct connection of the earth wires and the CCTV circuits. It is far safer to install inexpensive SPD's that are in series with each line. These provide excellent multi-stage hybrid performance and will open the circuit in event of a failure. Installing SPD's with a 10kA surge current capacity will ensure that when the surge exceeds the 10kA, the SPD fails, not the wiring.

Experience has shown that SPD's with higher surge current capacity on these circuits risks the wiring acting as a fuse link, becoming the weakest part of the circuit, rather than allowing the SPD to be sacrificed.

Adding an air terminal or lightning rod at the camera in the belief that it provides lightning avoidance or a "Cone of Protection" is seriously flawed. This paper has clearly shown the common mechanism for damage lies in the earth system. Installing an air terminal can potentially make things worse. An air terminal is designed to attract lightning to the tip of the rod, rather than attach to any other random location at the site. This is the basic principle of a "physical Lightning Protection System on a tall building. Installing the air terminal increases the probability that random lightning in the area will strike the terminal attached to the pole and result in an extreme elevated ground potential at that site.

<u>Conclusion</u>:

Professional Surge Protection installed on all lines, at both ends, cabinet and camera, will prevent 99% of all lightning related damage. This will only work if the surge protectors at the camera end are referenced to the pole ground. In addition, interconnecting the ground from each pole to the cabinet will significantly improve the overall earth system and reduce the impedance.

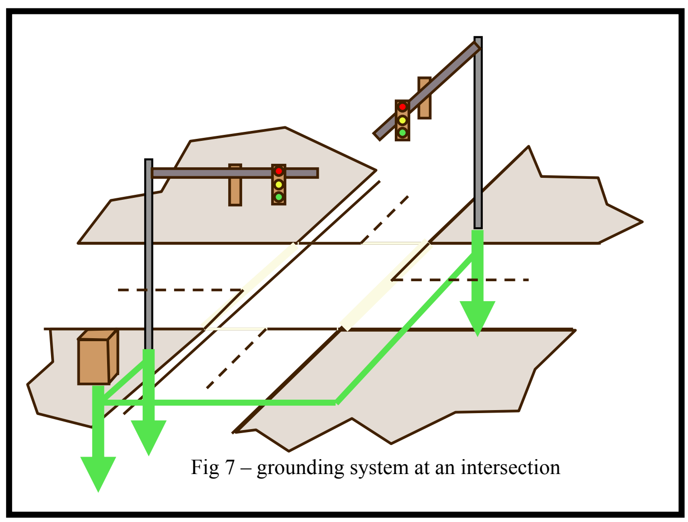


Fig 7 – grounding system at an intersection

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