Risk Mitigation of Lightning Incursion into Network Equipment Via PhotoVoltaic Systems

It's not easy being "Green"

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Abstract

Says Kermit the Frog, "It's not easy being green." Becoming "Green isn't cheap either. Forward-thinking telcos and data centers are considering photovoltaic (P.V.) panels as a way to save energy and exploit the very real public relations kudos to be had building "Green" facilities and features into their networks. Until recently P.V. systems were used only for very small installations typically less than a kilowatt. Such installations were used for sites that lacked available commercial power such as emergency roadside phones. Now, large array panels and systems are available with significant power capability and companies are considering placing P.V. systems in parallel with their commercial electric feeds or their d.c. systems.

With price tags in the tens of thousands of dollars per kilowatt of capacity, it might take awhile for a facility to realize a significant payback despite grants and financial incentives. Still, that lure of P.R. sees companies considering these relatively large P.V. systems. While it's great to build new systems, it's critical to protect telecommunications central offices, data centers and smaller facilities such as cell or microwave sites from lightning. There are several design considerations that can make the difference between a safe, sound P.V. system or one that is a virtual bayonet in wait of an opportunity to stab your company's network systems squarely in the power bus.

Typically, P.V. systems are installed as rooftop installations or in ground arrays mounted to frameworks. Each of these installations bears specific hazards of lightning or induced surge currents that could enter the network via the conduits or conductors that connect the P.V. system into the facility infrastructure. The lightning "hit" might be a direct stroke to the site or currents induced from strikes within a mile or more of the facility. A system-level approach to lightning and surge protection is prudent in order to protect the facility from damage. Most electrical engineers and contractors are well trained in ac distribution systems and to a lesser extent, dc systems. Lightning and lightning related surges, however, behave in ways that are very different from dc or low-frequency ac. Therefore, different skill sets and training are needed to approach P.V. systems from a lightning protection and surge suppression point of view. This paper will identify the finer points of bonding grounding (Earthing) and electrical protection as they apply to P.V. systems used in telecom network applications.

Threats

The principal vulnerabilities that photovoltaic systems bring to a telecommunications include susceptibility to lightning and to damage from Ground Potential Rise (GPR). In addition to damage to the panels, if the photovoltaic panels connect directly to the dc bus of the power plant feeding the facility, there is a very real possibility that a lightning strike could be coupled directly to the bus. Such an event would likely destroy any electronics connected to the bus and might result in explosive damage to the battery with any collateral damage that such a condition might precipitate. Clearly, a robust Lightning Protection System (LPS) and Surge Protective Device (SPD) are needed to protect such a system.

There are other photovoltaic systems on the market that provide a full power solution consisting of rectifiers, photovoltaic panels, a battery and then inversion to ac. The input to the telecommunications equipment therefore would be ac which would need to be rectified and presented to the electronics as dc. The output of these systems too, should be protected by a robust SPD. Additionally, if the photovoltaic system is arranged to send excess energy into the utility power grid, those systems employ a type of inverter called a "Utility Interactive Inverter" and such units require particular circuit breaker protection as is covered in the National Electrical Code (NEC) NFPA 70[(1)]. Articles 690.64 and 230.82(6).

Then too, the juxtaposition and lateral distance between outdoor cabinets such as a photovoltaic system and a telecommunications system contributes to the degree of difference in electrical potential during a Ground Potential Rise. The placement of photovoltaic systems may increase the likelihood of a direct lightning strike depending on where the system is with respect to the "Zone of Protection" offered by the tower or other antenna supporting structure. Accordingly, a critical need exists for reliable bonding and grounding (Earthing) of all systems for personnel safety and equipment protection.

Lightning Protection Basics

A simplified theory of lightning is that air currents of hot, humid air rising into the sky and cold dry air falling from it create molecular friction in clouds, not unlike the friction of one's feet across a carped on a cold dry day. A static electric charge is formed. As clouds become charged, the imbalance of electrons from one cloud to the next or from a cloud to the surface of the earth results in like polarity charges repelling and unlike polarity charges attracting. Where there is attraction between unlike polarities, an electrostatic current flow called "Stepped leaders" form between them and that path soon ionizes the air between them for a stroke of lightning to flow between them to equalize the imbalance of charge. These strokes might be cloud to cloud,

cloud to earth, or even something called a "Return stroke" which is a lightning stroke upwards from earth to a cloud.

The purpose of a lightning protection system is to give lightning currents a lower impedance alternative path to ground around the building or object being protected. This simple concept was born of Benjamin Franklin in 1752 with his kite experiment and development of lightning rods. Lightning is widely misunderstood and for more than a century after the development of lightning rods, their use was considered heresy by religious leaders. Despite church leadership proclamations that lightning was vengeance visited upon sinners, it was their steeples being struck as opposed to the much lower buildings in the communities[2]. During those years hundreds hired or volunteer bell ringers met an untimely and unheralded demise by electrocution.

Ranking high among the many myths surrounding the lightning phenomenon is the notion that lightning rods attract strokes. In reality, the rods do not attract lightning energy, they simply give the energy that's about to strike the building a safe, lower impedance path to ground via conductors sized to carry the charge and thus avoid fire or other serious damage to the building.

With that said, there is another type of lightning protection system called an "Early Streamer Emission" (ESE) system reported to improve upon simple lightning rods by triggering an early upwards streamer/leader at a time, delta T, earlier than the triggering time of a simple lightning rod. The time difference, delta T, is defined as the time advantage. It is touted that this time advantage is multiplied by a constant velocity of the upwards progressing discharge. The velocity multiplied by delta T determines the length, delta L, of the triggered discharge.

The superiority claims about ESE systems were analyzed by members of the Scientific Committee of ICLP (International Conference on Lightning Protection). These scientists issued a joint statement opposing ESE lightning rod technology [2]. The scientists represent 15 countries including the USA, Japan, Great Britain and 12 countries from Continental Europe, and 14 of them are well-known university professors. Essentially their finding is that ESE systems perform no better than their simpler, less expensive cousins, the simple lightning rod.

The NFPA has declined to issue a standard for ESE systems. Accordingly, the industry consensus seems that simple lightning rod systems are the preferred means of lightning protection.

Zone of Protection

"Zone of Protection" is a term used to describe areas on a building or other structure that are unlikely to suffer a direct lightning strike because taller objects tend to be struck instead. Lightning protection engineers use a theoretical sphere of 150 feet (46 Meters) to determine air terminal (more commonly called "lightning rod") placement on buildings or other structures. Underwriters Laboratories (UL) UL96A [4], Lightning Protection Institute (LPI) LPI-175 [5]. and National Fire Protection Association (NFPA) NFPA 780 [6] are industry standards for lightning protection systems. The mathematical overlay of a series of theoretical spheres over a building or the air terminals placed on a building determines where to place nearby air terminals so that all parts of the building are protected.

Figure 1 is a redrawn (for clarity) excerpt from LPI-175 and shows a series of 150 foot (46 Meter) Radius spheres overlaid atop lightning rods placed along the roofline of a building. Because no part of any of the spheres touch the building, all parts of the structure fall within the "Zone of protection" afforded by the lightning rods. If part of the sphere touched the building the system designer might space the rods closer together or use longer lightning rods. In either case, so long as the theoretical spheres do not touch the building all is well.

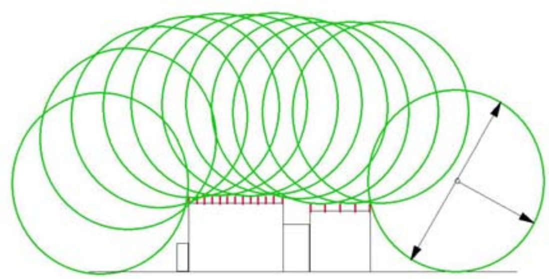

Figure 1 Redrawn figure from LPI-175 showing 150' Radius (300' Diameter) spheres used to determine the effectiveness of a lightning protection system for a building.

Figure 2 also is redrawn from LPI-175 and shows a multi-level roof protected by lightning rods. The arcs shown in the illustration represent the arc radius of a 150 foot sphere. Note that the spheres (arcs) only touch the building at the lightning rods indicating that all parts of the building fall within the "Zone of protection".

The illustration in Figure 3 shows a cell or microwave site where photovoltaic panels are placed on the roof of a typical precast telecommunications equipment shelter. During cold climates towers, antennas and mounts often develop ice encrustations that eventually fall away, often in large chunks (Figure 4). Typically, waveguides or antenna coaxial cables running from the tower to the shelter are shielded from falling ice by a steel protective structure called an "Ice bridge." Obviously, placing a steel structure between a photovoltaic panel and the sky is imprudent and so it is necessary to place photovoltaic panels a safe distance from anything that might fall from the tower. At this distance the panels may or may not lie within the Zone of protection from lightning afforded by the tower and a 150 foot “rolling ball” determination needs to be made.

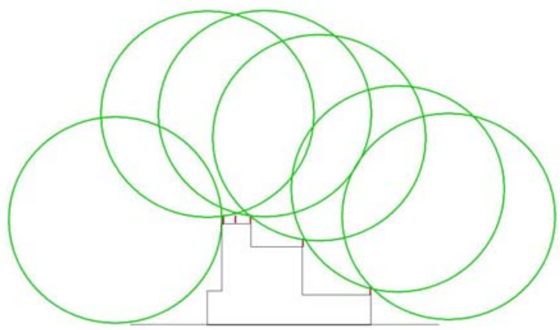

Figure 2 Redrawn excerpt from LPI-175 showing 150’ Radius spheres used to determine the effectiveness of a lightning protection system for a multi-level building.

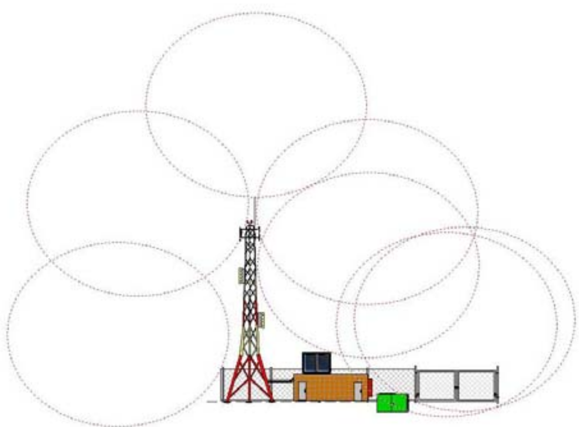

Figure 3 Sketch of a cell / Microwave site where the photovoltaic panels may need lightning protection because the distance from the tower may place the panels outside the arc of a 150 foot Radius ball and therefore outside the Zone of protection afforded by the tower.

Once the decision is made to add lightning protection to photovoltaic panels which of the many forms is best for a given application? For small systems of only a few panels, often a simple lightning rod arrangement is best. The rods might be attached directly to the structure supporting the panels or on masts mounted near to and above the panels. It is prudent to employ the services of a professional lightning system designer such as one affiliated with the Lightning Protection Institute or the United Lightning Protection Association. These organizations provide testing and oversight to the appropriate skill levels needed to correctly design and install a lightning protection system.

Figure 4 Heavy ice encrustation on a tower can fall away in large chunks posing a threat to unprotected equipment below.

The information presented herein is not intended to replace a professional design or act as a “cookbook” for lightning protection. Rather, the information herein is intended to give the reader an idea of the basic fundamentals of lightning protection to gain an understanding of the need for such protection and provide “talking points” and a frame of reference when dealing with lightning protection professionals.

Lightning rods and conductors typically are made from copper or aluminum and so it is important to select materials that are compatible with the metals used in the structure. For example, copper hardware on an aluminum structure will create corrosion conditions and so a properly designed lightning protection system will handle dissimilar metals very carefully. Additionally, the overall height of the structure determines which class of lightning protection components need be used. Class I components are intended for use on structures not taller than 75 feet (22.9 Meters). Class II materials are intended for use on structures taller than 75 feet (22.9 Meters).

The wiring for lightning protection systems usually is not insulated. Under normal circumstances the conductors are at ground potential and don’t need insulation and when carrying lightning currents the wire may become hot enough to burst insulation into flame and initiate collateral fires.

Because lightning has a very sharp rise time, typically about 1.2 microseconds (Figure 5) the energy imposed by lightning influences behaves as high frequency energy. Electrical energy at frequencies in the Radio Frequency (RF) range behaves differently than energy at relatively low frequencies such as dc and 60 Hz. Accordingly, multiple paths to ground and long radius conductor bends become extremely important in the design of lightning protection systems. Otherwise, the intended "safe path" for lightning strike or lightning induced current is degraded by increased circuit impedance and the amplitude of unwanted voltages is increased.

The principles of providing lightning protection for a photovoltaic system are no different than those protecting a home or other building. The air terminals should be placed on the highest part of the structure and at least two down conductors placed with long radius bends shall connect to ground rods driven into the earth. Where chimneys or other structures rise above a roof, air terminals are placed upon it and at least two conductor paths connect it to Ground (Figure 5).

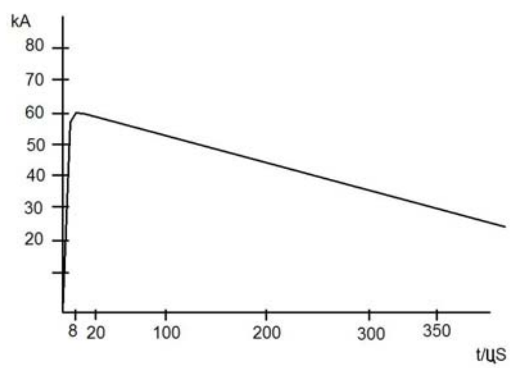

Figure 5 Standard test waveform used for SPDs intended for lightning protection

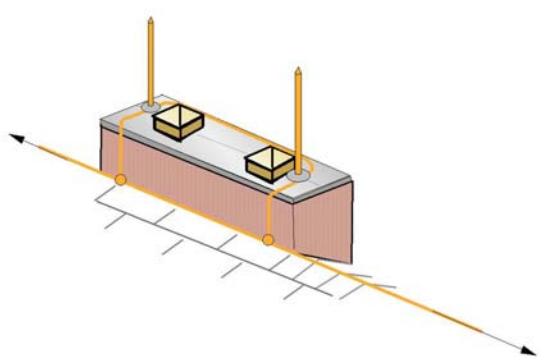

Figure 6 Redrawn excerpt from LPI-175 shows Air Terminals on a chimney connected to a conductor running along the ridge of a roof and at the ends of the roof the conductor will run down the structure and be connected to ground rods buried in the earth.

Similarly, if photovoltaic panels are equipped with lightning rods, the rods would be placed near the ends of the panels and provided with at least two wiring paths to the earth ground electrodes (ground rods). The rods would be mounted vertically on the structure supporting the photovoltaic panels and a suitable conductor run across the top of the structure connecting both Air Terminal bases and then running downwards to the driven earth electrodes or buried ring if the facility is so-equipped. Additionally, to prevent flashover burns, the framework of the photovoltaic panels should be bonded to the down-conductors as is shown towards the bottom of Figure 6.

As was mentioned previously, some photovoltaic systems are complete ac and dc power systems with internal batteries, rectifiers and inverters, and some even include a standby generator package. Leased space at cell or microwave sites often is at a premium and so the equipment "footprint" needs to be as small as is practicable. Also, the system needs to be well bonded and grounded among the various components and also with the systems comprising the cell or microwave systems they serve. Figure 9 illustrates the bonding connections of a typical cabinetized photovoltaic system with a standby engine system and also a cabinetized cell and/or microwave site. Note that in the illustration each cabinet has two connections to the down-conductor with each connection steering on opposite directions. This is done to minimize the impedance of the ground-path circuit no matter which direction the lightning influence is coming from.

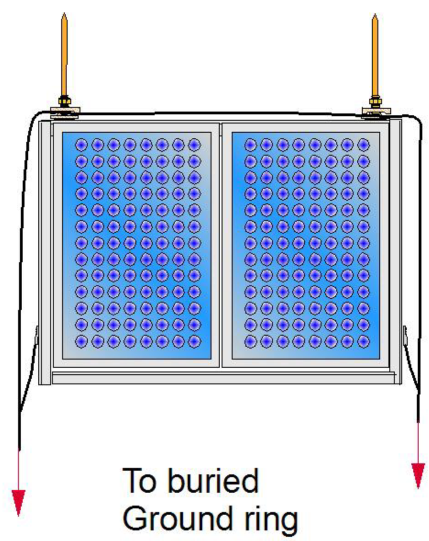

Figure 7 Front view of Air Terminals mounted on the supporting structure for photovoltaic panels. Note also that the panels and structure themselves are bonded to the system to prevent flashover damage.

Some companies are considering large scale photovoltaic systems at central offices, either on rooftops or at ground level behind the building. Decisions about whether or not these systems require lightning protection should be based upon risk. NFPA 780 Annex L has a good risk assessment procedure that can help decide whether lightning protection is warranted for a given facility.

Where lightning protection is warranted, the task at hand is to determine what type of a system is warranted. For some installations, a common Air Terminal is mounted on a mast and connected to a ground rod. Such a mast is placed at intervals along the photovoltaic “farm” as determined by the standard 150 foot arc and the system is protected. The masts should be bonded together. For such systems it is important that the sun shadow caused by the masts makes a minimal impact on the solar panels so that the system maintains its efficiency.

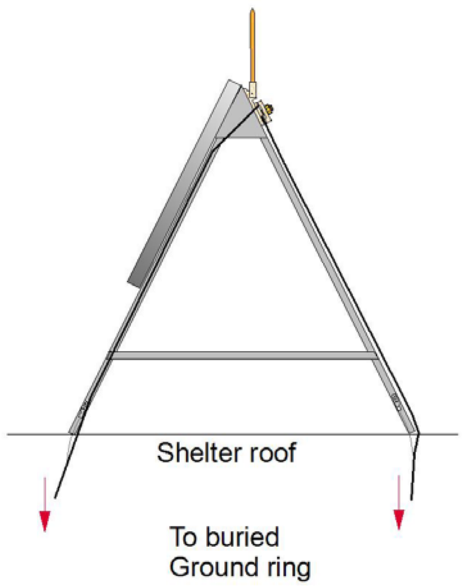

Figure 8 Side view of Figure 7.

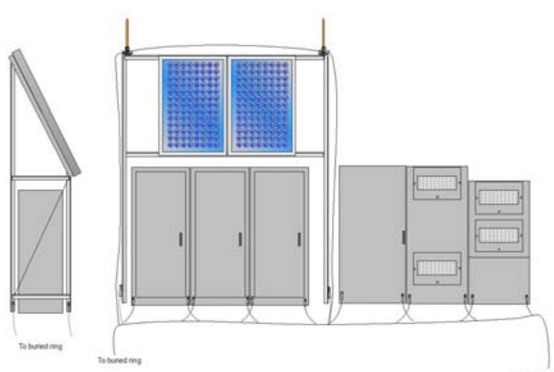

Figure 9 Side and front views of the bonding interconnect between a typical photovoltaic system (left) and a cabinetized cell or microwave system (right). The legend information at the bottom of the sketches reads, “To Buried Ring” referring to the earth ground electrode system.

Often, a less expensive alternative to mast type systems is a catenary wire system. Grounded catenary wires are used to protect ships and also high voltage electrical transmission lines. That same technology provides an inexpensive means for protecting a large rooftop or field installation.

Usually, for large rooftop systems dc from the photovoltaic panels is conducted into the building and then connected to utility-interactive inverters that run in-phase with the building’s electrical system. There is the concern that lightning might strike a panel or wiring and be conducted into the building thus destroying the inverters or other electronics. Using an SPD device at the rooftop and inverter ends of the dc wiring is a good idea. Another idea is to use a metallic raceway such as rigid aluminum conduit and to ground the conduit using a technique similar to the way that tower waveguides and coax cables are bonded.

Figure 10 A large scale photovoltaic system

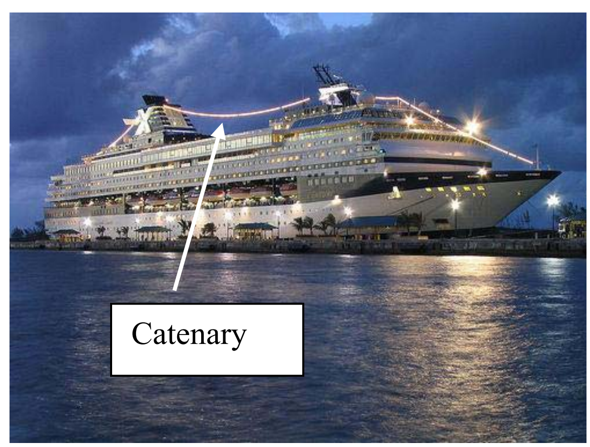

Figure 11 A grounded catenary wire protects a ship from lightning by offering a safe, low impedance path to the water via the wire and the hull of the ship.

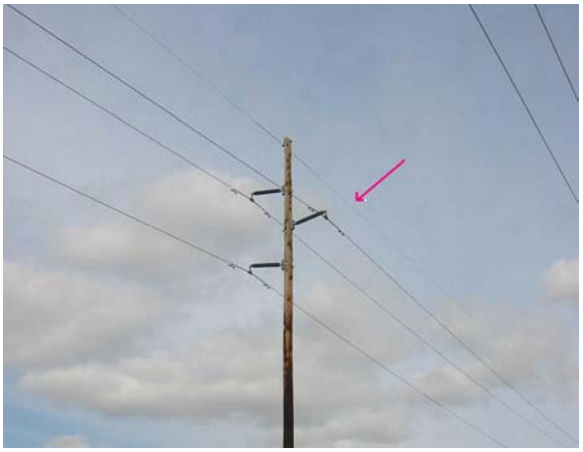

Figure 12 A grounded catenary wire (Arrow) protects a power transmission line from lightning.

Figure 13 Placing one or more catenary wires on a rooftop is an inexpensive yet reliable way to provide lightning protection for a large rooftop photovoltaic installation.

At a cell or microwave site, the conductors coming down the tower to the shelter make a deliberate sharp bend at the bottom of the run (Figure 14). At this point, a ground conductor is bonded to the waveguide or coax shield and run in a straight path to earth ground electrodes. The methodology is that sharp bends offer a relatively high impedance path to high frequency electrical currents such as a lightning strike or inducted lightning event. The straight conductor going to ground offers a low impedance path. Accordingly, most of the lightning energy will follow the straight path and only a tiny fraction of the current will follow the bend to the shelter. Typically, a #6 AWG (17 mm) or a #2 AWG (43 mm) stranded copper wire is used for such bonding.

Ground Potential Rise (GPR)

Another lightning protection issue is protection from Ground Potential Rise (GPR). When lightning strikes the surface of the Earth, it raises the electrical potential of the soil in the immediate vicinity. That electrical charge travels across the surface of the earth in all directions. Because soil has varying amounts of Resistivity due to moisture and mineral content, the soil at the surface "looks" like a series-parallel resistor network extending nearly a quarter mile (440 Meters), also in all directions. Like any resistor network, a voltage division will occur. In this case, the center of the network bears the full-on voltage of the lightning stroke and the edges remain at zero potential and everywhere in-between has a certain amount of voltage drop.

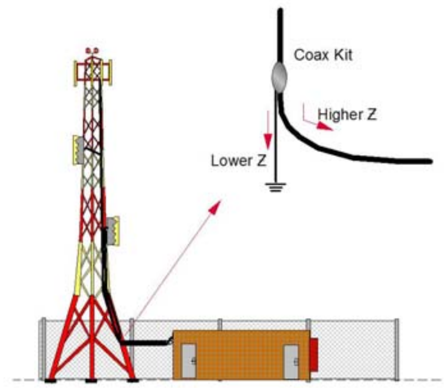

Figure 14 Coax grounding kits connect to the coax shield or waveguide body just above a sharp bend in order to provide a low impedance to lightning currents going towards ground and a relatively high impedance to lightning currents traveling towards the radio systems.

This voltage drop can be quite large close to the site of the lightning stroke, often in the thousands of volts. Known as a "Step Potential" this energy is well known to have caused deaths in livestock and even in humans out walking near the lightning strike. Because of this step potential, objects such as telecommunications cabinets mounted only a few feet apart can bear damaging, even lethal electrical potentials between them and so bonding becomes very important from a safety and reliability viewpoint.

Another term, "Touch Potential" is used to describe electrical potentials that result when two objects with significantly different electrical charges are close enough together that a person could touch both of them at the same time and thus, become a conductor to currents flowing to equalize the electrical potential difference between the two objects. Six feet (2 Meters) is generally considered the critical distance for touch potentials. Metallic objects with six feet or fewer between them should be bonded together to provide a safe alternative path for the energy, thus protecting humans who might be present. Such a bond connection is shown in Figure 13 near the roof, where the electrical conduits for the photovoltaic equipment are bonded to the lightning rods and conductors on the parapet wall. Figure 14 also shows bonding, in this case of photovoltaic panels arranged in rows on a roof top. Similar bonding should be provided if the photovoltaic system is installed at ground level, in a field perhaps as the one shown in Figure 10.

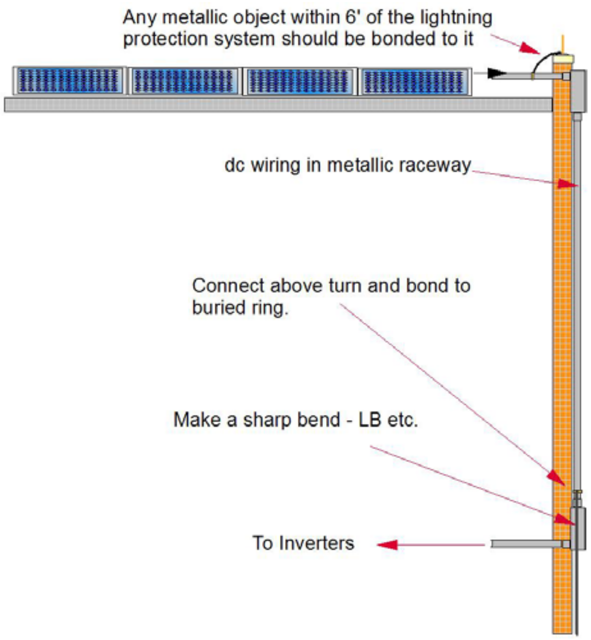

Figure 15 By using metallic raceway and bonding it as shown there is much less likelihood that lightning currents will enter the building via the photovoltaic system wiring from rooftop PV panels.

Carrying that thinking just a bit further, it is prudent to bond equipment elements that are cabled together, referenced to different grounding (Earthing) electrodes and might be some feet apart (Figure 15). Typically, a #2 AWG (43 mm) solid copper wire is used for such bonding. If the wire will be exposed to sulfur compounds of any sort either in the air or present in the soil it is prudent to use tinned wire because sulfur attacks and corrodes copper.

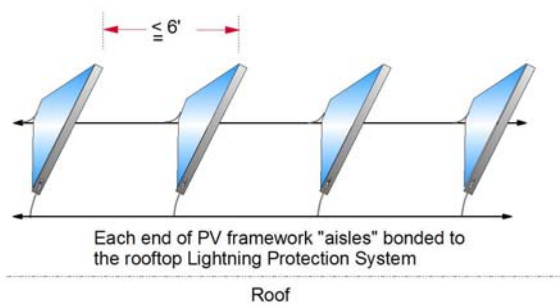

Figure 16 Rows or aisles of photovoltaic panels should be bonded together especially if they are fewer than 6 feet (2 M) apart.

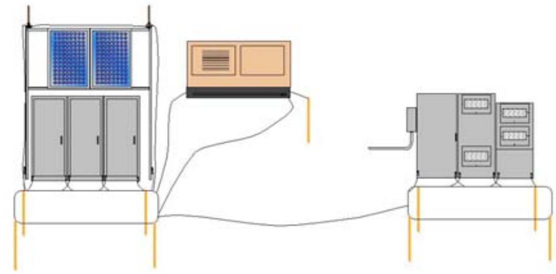

Figure 17 In this sketch, a photovoltaic power system (left) a standby generator (center) and a cell or microwave system (right) all are referenced to different ground (Earthing) electrodes and are bonded together by bare #2 AWG (43 mm) wire. The wiring is buried but shown here without soil for clarity.

Surge Protective Devices (SPD)

Good surge protective devices are relatively inexpensive protection for personnel and equipment and need to be a big part of any reliable photovoltaic installation. Unfortunately, there are many misconceptions about the use and installation of such devices. As was covered herein, electrical currents from lightning strikes whether a direct strike or currents induced into conductors from their exposure to expanding and then collapsing electromagnetic fields of nearby lightning strikes, all have a sharp rise-time and therefore behave as high frequency energy. Similarly, power line transients caused by the switching of large loads, Power Factor correction capacitors or other utility line connected equipment also behave as high frequency energy. Lastly, load-generated events such as air conditioning compressor motors starting or stopping also cause transients on the electrical feeders. The waveform for power line transients usually has a very sharp, needlelike rise time and decay time which is why they often are called “Spikes” in the industry because thee waveform resembles long carpentry nails, also called “Spikes”.

As was mentioned earlier herein, high frequency energy behaves differently than relatively low frequency energy. This is why high frequency switchmode rectifiers are so much smaller and lighter than older types of rectifiers. The higher frequencies are more affected by the electromagnetic properties of induction, capacitance etc and so the reactive physical components such as transformers, inductors and capacitors can be significantly smaller and do the same job. Even wire “sees” much more effects from induction when the frequency of the energy traveling that wire is high. Further, sharp bends in that wiring add dramatically to the induction “seen” in a circuit. Therefore, it is an electrical imperative that all wiring connecting SPDs to a circuit and grounding (Earthing) that SPD be as short and straight as practicable and that sharp bends in that wiring be avoided.

These wiring issues are critical to reliability whether the SPD is a large Transient Voltage Surge Suppressor protecting a Service Entrance (Mains), a Protector terminating telephone cable or alarm lead or a lightning arrestor protecting an antenna feedline. All of these SPDs need to be wired and grounded (Earthed) very carefully. Every SPD has a certain amount of unwanted surge voltage that passes through the device without attenuation called a "Let through Voltage." SPDs are chosen for a let through voltage and current carrying capability based upon the circuit application. As the lead length between the circuit to be protected and the SPD and between the SPD and Ground potential increase, so does the let through voltage. In fact, the let through voltage increases dramatically with lead length or sharp bends in the leads. Every effort should be made to minimize the lead length and assure that leads are run correctly.

Most SPD devices intended for protecting utility Service Entrances (Mains) have a finite amount of energy that they can absorb before failing. Usually the Metal Oxide Varistors (MOV) or Avalanche Diodes within them burn open leaving the circuit unprotected. Many of these units are specified with Form-C contacts to provide remote alarm indications when the SPD has failed. If SPD devices are placed any significant cabling distance from the equipment area, there is the likelihood that large surge voltages could impinge upon the alarm leads in a manner similar to the "Step potential" covered earlier. Most SPD alarm leads are not SPD protected and the unwanted voltages on the alarm leads could cause damage to an alarm scanner circuit. Therefore, it is necessary to protect such leads with a suitable Primary SPD device where the alarm leads enter the structure or cabinet where the scanning device is housed (Figure 16). Underwriters Laboratories (UL) Standard 497[(7)], 497A [(8)], and 497C[(9)] cover SPDs for communications leads, control leads and for coaxial cable protection. Additionally, American National Standards Institute (ANSI) Standards T1.313 [(10)] and T1.316[(11)] cover SPD protection for telecommunications wiring.

Of the types of SPD covered under the UL 497 series, several types are included as follows:

UL497 – These Protectors are listed for use as Primary protection in communication circuits as defined in Article 800 of the *National Electrical Code*®. This category includes both fuse and fuseless type protectors. These devices may also be used to protect against electrical transients from electromagnetic disturbance produced by lightning and similar high voltage event.

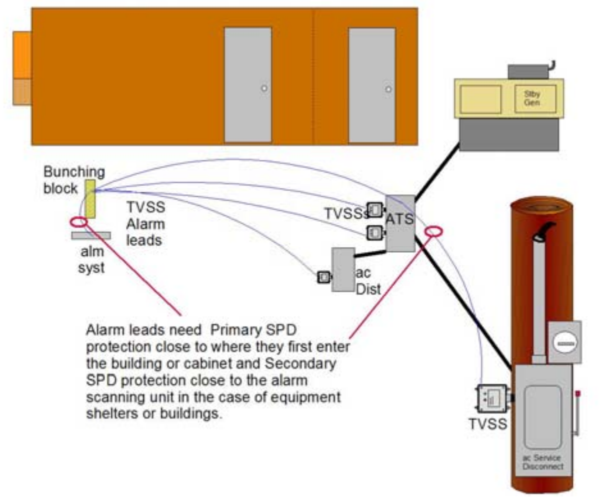

Figure 18 Transient Voltage Surge Suppressor installed at the Service Disconnect (Mains) has alarm leads that also need SPD protection or GPR may impress damaging voltages on the Alarm leads.

UL 497a **-** These protectors are evaluated for use as secondary protection in communication circuits as defined in Article 800 of the *National Electrical Code*®. They are intended to suppress abnormal voltages and/or currents that bypass the primary protector. They have been evaluated for use only on the equipment side of a primary protector.

UL 497B **-** These devices are intended for use on Isolated Loop Class 2 or Class 3 remote control signaling and power limited circuits. These devices may be used to protect against electrical transients from electromagnetic disturbance produced by lightning.

UL 497C **-** These protectors are evaluated for use in coaxial circuits as defined in Article 830 of the *National Electrical Code*®. This category includes both fuse and fuseless type protectors. These devices may also be used to protect against electrical transients from electromagnetic disturbance produced by lightning.

Although there are many physical forms for primary SPD protectors the most common type used in telephony is the five-pin plug in module type (Figure 19).

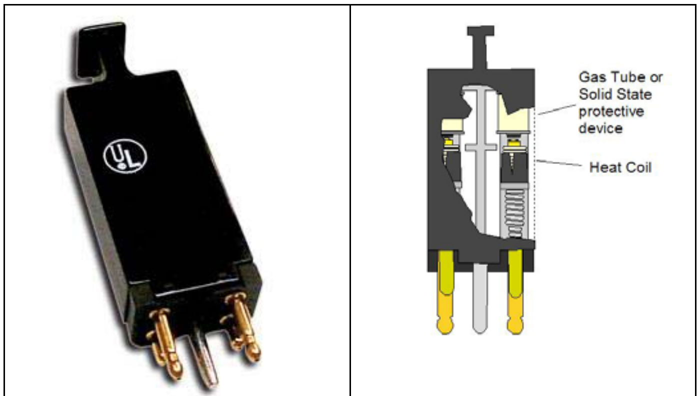

Figure 19 Five-pin primary protector photo and cutaway sketch. Heat coils are optional on most protectors and are designed to protect against "Sneak" currents by operating and connecting the leads to Ground.

Secondary protectors take many physical forms and utilize a variety of connecting schemes including wire land terminations, plugs and sockets. SPD devices protecting Ethernet or T-1 type connections usually are provided with 8-pin RJ-45 connections.

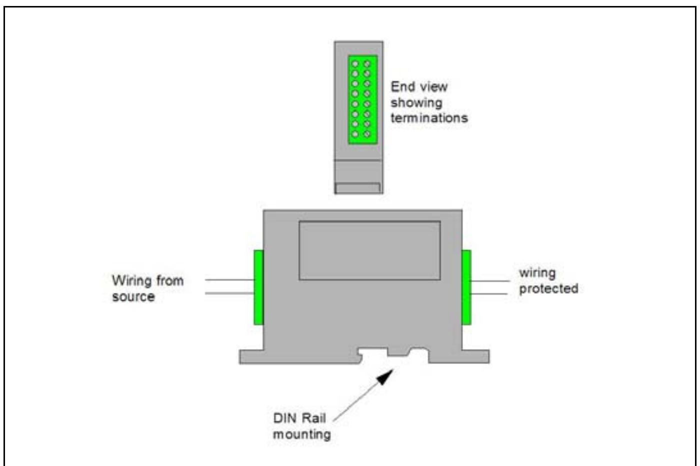

Figure 20 A typical protector unit. This model is arranged for DIN rail mounting and would obtain Ground from the DIN rail.

Figure 21, a poorly grounded protector mounting. Note the Flashover burn evident just behind the grounding bar to the left of the wire.

Standard UL1449 covers TVSS devices for protecting commercial power wiring. [12] The third Edition of UL1449 becomes mandatory in September of 2009 and provides listing and marking requirements for three type-classifications of SPD intended for ac power connections as follows: [13]

Type 1 — Permanently connected SPDs intended for installation between the secondary of the service transformer and the line side of the service equipment overcurrent device, as well as the load side, including watt-hour meter socket enclosures and intended to be installed without an external overcurrent protective device.

Type 2 — Permanently connected SPDs intended for installation on the load side of the service equipment overcurrent device, including SPDs located at the branch panel.

Type 3 — Point-of-utilization SPDs, installed at a minimum conductor length of 10 m (30 ft) from the electrical service panel to the point of utilization, e.g., cord connected, direct plug-in, receptacle type and SPDs installed at the utilization equipment being protected. The distance (10 m) is exclusive of conductors provided with or used to attach SPDs.

When writing specifications for photovoltaic installations it is prudent to determine if suitable SPD devices can be found that meet the new 3rd Edition requirements for UL1449.

One criterion for specifying SPDs for TVSS applications is which modes of protection are needed. The various Modes include Line to Ground, Line to Line, Line to Neutral and Neutral to Ground protection. With grounded Neutral leads often there is the thinking that protection is not needed for the Neutral lead. Depending on the application this may or may not be so. By Code, the Neutral and Equipment Ground are bonded together by a conductor called the "Main Bonding Jumper." Also by Code, the main bonding jumper is placed at the Service Entrance (Mains).

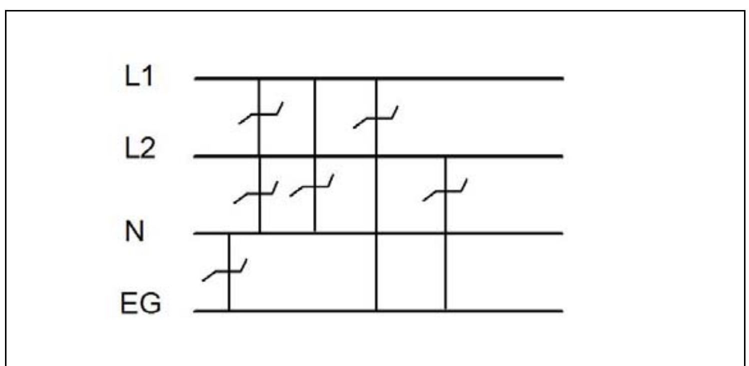

Figure 22 "All-Mode" TVSS protection, Line to Line, Line to Ground, Line to Neutral and Neutral to Ground.

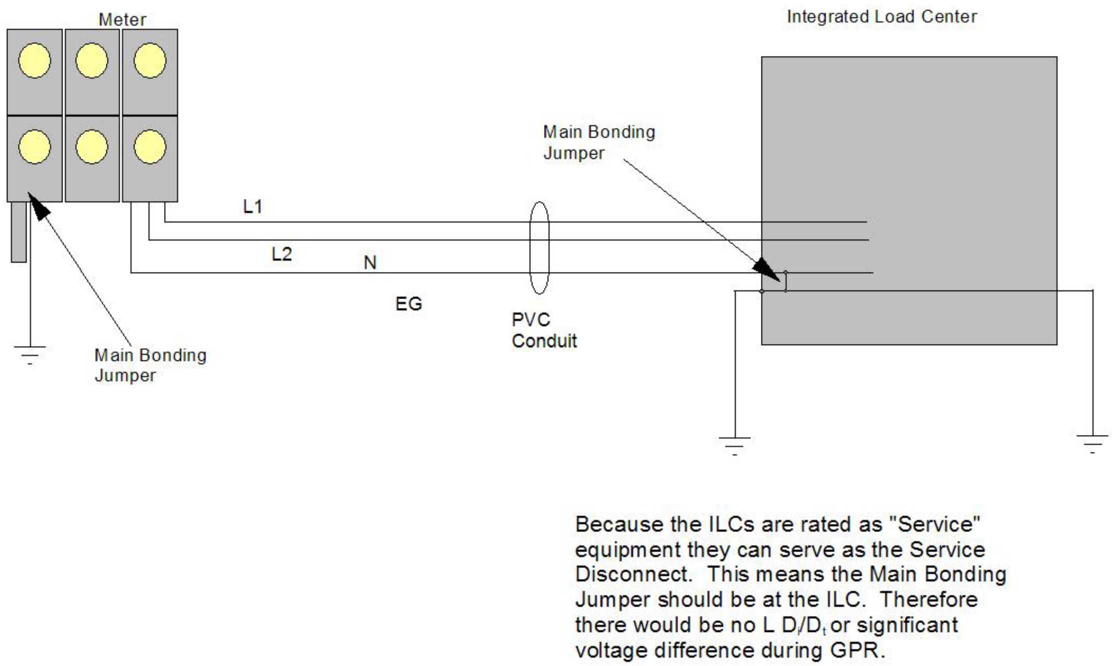

Figure 23 One "work around" for the problem created when the Neutral to Ground Main Bonding Jumper is far from the site equipment. Establish a bonded Neutral at the equipment. It is critical that nonmetallic conduit be used between the service entrance and the facility. This stipulation is to avoid unwanted Neutral current on a metallic conduit.

A great many cell sites are collocated with other cellular service providers who rent real estate space at the site and antenna space on the tower. Ordinarily utilities provide a single large multi-tenant service entrance with multiple meters and by Code, the Main Bonding Jumper is located there. With each cell site a hundred feet or more (33 Meters) from the Neutral to Ground bond, a GPR is capable of impressing enough voltage onto the Neutral conductor that damage to equipment can result. Under such conditions, Neutral to Ground SPD protection makes sense. Another practical approach [(14)] shown in Figure 23 is to use nonmetallic conduit from the multi-tenant Service Entrance and not include an Equipment Ground conductor. Then, at the cell site, place a Service Disconnect or a Service rated Integrated Load Center (ILC) referenced to the grounding (Earthing) electrodes for the cell or microwave site and establish a Neutral to Ground bonding jumper in the Integrated load center. By doing so the Code requirements are met and the problem of large impressed voltages on the Neutral conductor is eliminated.

Conclusion

A photovoltaic system is a costly investment and deserves well-reasoned solidly engineered systems and sub-systems to protect that investment from lightning, GPR or other destructive surge. A systems engineering approach that offers a considered solution to all of these perils makes sense from a safety, reliability and economic sense.

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