

# Installation Guide for Smart Grid Applications

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## 1. Background

The development of the Smart Grid (SG) may entail the interconnection of numerous consumer electronic devices and appliances to each other and to the outside world. As devices become more interconnected the importance of proper installation practices with respect to electromagnetic compatibility (EMC) and electromagnetic interference grows. The primary phenomena associated with EMC and EMI are lightning strikes, which can result in high energy surges and fast transients on a building's power and communications wiring and its grounding system; electrostatic discharge, which is a form of fast transient that is exacerbated by low humidity; and conducted and radiated radio frequency (RF) energy from equipment power supplies, florescent ballasts, welders, switching, wireless communications devices, dimmers, and other sources.

The first line of defense against these problems is good installation practices including:

- Proper lightning protection outside the building
- An understanding of proper grounding practices
- Surge protection on all wires entering or leaving the building
- Local surge and fast transient protection for sensitive equipment on both power and communications connections to a device
- Proper wiring installation practices
- An understanding of the issues relating to wired, wireless and powerline carrier networks

## 2. Purpose

This Installation Guide was developed to provide the reader with a basic understanding many of the issues related to the proper installation and protection of Smart Grid devices and systems they connect to. It is not intended to be a complete source of solutions for all situations, nor as a replacement for an understanding of, and compliance to the laws and regulations as defined by the FCC, the National Electric Code (NEC) and other federal, state and local codes and regulations. It should be seen as a starting point for consumers, installers, and companies involved in buying, developing, or installing smart grid technologies and devices. References are included in an appendix for those interested in learning more about this important subject.

## 3. Building Protection

A lightning strike in the form of either a direct hit on the building, on the grounds and objects surrounding the building, or on or near wires entering or leaving the building can create huge voltage

potentials that can damage equipment and even cause fires (see figure 1). Therefore it is crucial to minimize the amount of energy that actually enters the building's wiring through the use of building protection. This is especially true for areas that experience high incidence of lightning storms.

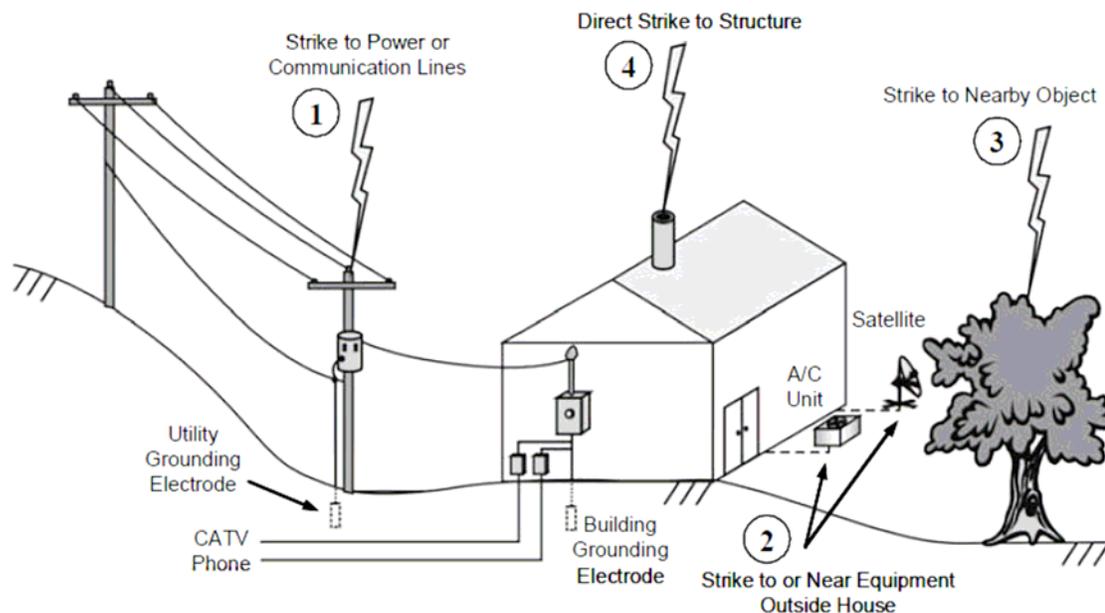


Figure 1: Ways Lightning Can Enter Your Home<sup>1</sup>

To determine the incidence of lightning strikes in your region and therefore the risk your home faces go to: [http://www.lightningsafety.noaa.gov/lightning\\_map.htm](http://www.lightningsafety.noaa.gov/lightning_map.htm)

Of course this map does not necessarily provide a good predictor of how often your home may be subjected to lightning induced surges. For example if your home is located at the highest point in the area such as in an open field or on top of a hill it may have a higher chance of being affected by the occasional lightning storm than a home surrounded by higher structures in an area that experiences many more lightning storms. Additionally, high earth resistivity affects the severity of lightning strikes. Because of this the Northeast United States has some of the most violent thunder storms in the US.

Building protection consists of (see figure 2):

- One or more capture devices – lightning rods or the equivalent, also called air terminals

<sup>1</sup> IEEE How to Protect Your House and Its Contents from Lightning  
[http://www.lightningsafety.com/nlsi\\_lhm/IEEE\\_Guide.pdf](http://www.lightningsafety.com/nlsi_lhm/IEEE_Guide.pdf)

- Down-conductors which conduct the energy from the capture device down the side of the building to the grounding electrode system (earth)
- The grounding electrode system

The purpose of building protection is to divert the energy from a lightning strike away from your home and sensitive equipment and into the ground where it is dissipated. Without it the energy from a lightning strike will find the path of least resistance which may be the wires leading to your TV, computer, or other electronic devices. Due to the high voltages involved, it may also result in a breakdown of the insulation on your home's wiring which can result in a fire.

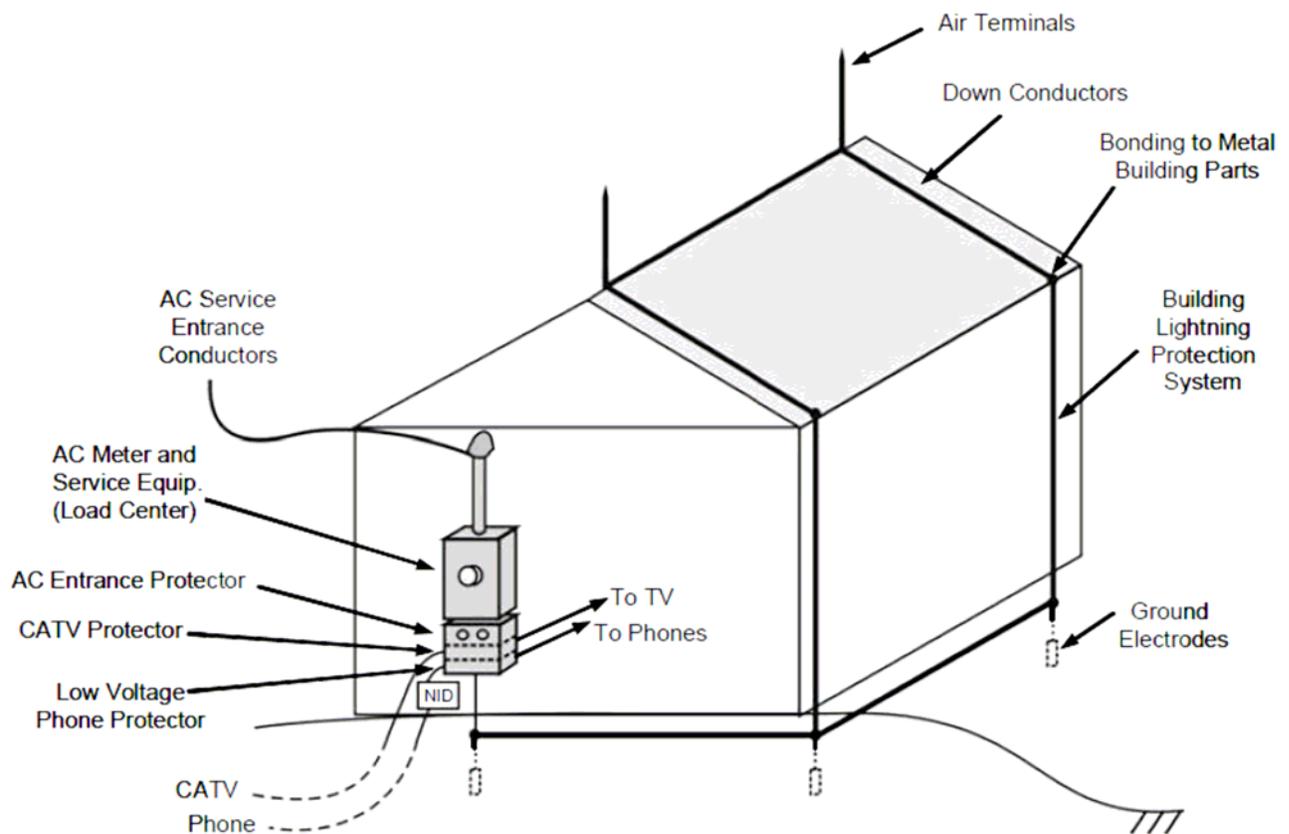


Figure 2: Building Protection<sup>2</sup>

### 3.1 The Capture Device

The most common capture device is a lightning rod although [NFPA 780](#) defines a number of other devices that can serve as capture devices. A lightning rod is a metal rod attached to

<sup>2</sup> IEEE How to Protect Your House and Its Contents from Lightning  
[http://www.lightningsafety.com/nlsi\\_lhm/IEEE\\_Guide.pdf](http://www.lightningsafety.com/nlsi_lhm/IEEE_Guide.pdf)

the highest point on the roof of a building and connected by a conductor to the building's grounding electrode system. The following is taken from [NFPA-780](#) and [NEC 70](#). It should be noted the following is not an extensive list of all requirements as stated in NFPA-780 and NEC 70. Also there are numerous exceptions listed in these documents. A qualified installer should be consulted for your particular building.

### 3.1.1 Recommendations/Requirements<sup>3,4</sup>

- Lightning rods should extend a minimum of 10 inches above the structure being protected and spaced 6 meters (20 feet) apart along ridges and within 0.6 meter (2 feet) of ridge ends.
- Additional lightning rods should be attached within 0.6 meter (2 feet) of outside corners of all chimneys. A single rod will suffice for chimneys less than 2' across. Use multiple rods for larger chimneys.
- All projections from a roof such as TV antennas, satellite dishes, and weather vanes should be bonded to the building's grounding electrode system.
- Gutters and other grounded metallic structures within 6 feet should be bonded to the lightning rod grounding system.
- Lightning rods and other capture devices should have 2 paths to the grounding electrode system.

## 3.2 Down (Grounding) Conductors

The down conductors are the wires that connect the capture devices to the grounding electrode system. They conduct the lightning energy from the lightning rods down the sides of the building and into the grounding electrode system where it is dissipated.

### 3.2.1 Recommendations/Requirements

- There must be at least 2 paths to the grounding electrode system (minimum 17 AWG for copper wiring, 14 AWG for aluminum) for each lightning rod or other capture devices.
- Down conductor(s) should connect to the grounding electrode system at the nearest practicable point and be installed as straight as possible, i.e. no sharp bends.

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<sup>3</sup> <http://www.elec-toolbox.com/usefulinfo/lightprot.htm>

- Do not use a downspout or any other “temporary” or non-continuous metal structures as a grounding conductor.
- Where possible keep lightning down conductors a minimum of 6 feet from CATV/satellite and phone wires. (NEC 70 articles 820-10 and 800-13).
- Any equipment installed on the outside of a building should meet the 6 foot separation requirement unless it has a metallic enclosure bonded to the lightning system conductors in locations less than 6 feet from it (NEC 70 250-46).

### 3.3 Grounding Electrode System

The proper installation of a grounding electrode system is critical to protecting against lightning strikes.

#### 3.3.1 Recommendations/Requirements

- A minimum of 2 ground rods, each at least ½ inch in diameter and driven at least 10 feet into the ground and bonded together, more for larger homes. However, this is only a guideline. For example areas with sandy soil require additional precautions such as a buried mesh.
- One of the grounding electrodes should be located as near as possible to the electric utility service entry and bonded to the utility ground to minimize the voltage potential between the utility ground and the grounding electrode system.

### 3.4 Grounding – General

See NEC 70 article 250 H and NFPA 780 for more details.

The reason for bonding all grounding electrodes to each other and to the utility ground is that a lightning strike can generate extremely high currents very rapidly (on the order of microseconds) which, due to the earth’s impedance, can result in a potential of thousands of volts between the grounding electrodes and between the electrodes and the utility ground. Equipment within the home depends on the ground connection as a common reference point. When the reference point (the ground) differs between two pieces of equipment that may also be connected to each other through communications wiring the circuitry can be subjected to extremely high voltages and currents damaging the circuitry.

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<sup>4</sup> <http://www.nfpa.org/aboutthecodes/AboutTheCodes.asp?DocNum=780>

This issue extends to the wiring within the home as well. Establishing common, low impedance grounds for all connections to your devices including both the line voltage wiring and the low voltage wiring is crucial. For example using the same receptacle wherever possible (ensuring you do not exceed the rated current for the outlet) for co-located and connected equipment ensures they are connected to a common ground minimizing the voltage differential they will experience during a surge event. A surge strip plugged into a receptacle will of course provide a common ground to everything plugged into it.

Of course equipment connecting to each other over a network cannot share a common receptacle. Therefore it is even more important to use point-of-use (plug-in, surge strips, etc.) surge protection for both the line and low voltages to those devices.

Ensuring your devices are grounded also helps to minimize damage from electrostatic surge – static electricity. Never cut off the ground connection on 3 prong (grounded) plugs and always use a 3-prong extension cord for devices that have a 3 prong plug. Devices with 2-prong plugs were designed to operate safely without a ground connection. Devices with a 3-prong plug are designed to have a ground connection. Finally, the best defense against damage from static electricity is humidity. Keeping the humidity at a minimum of 35% will help to minimize the risk of damage to your equipment from a static discharge.

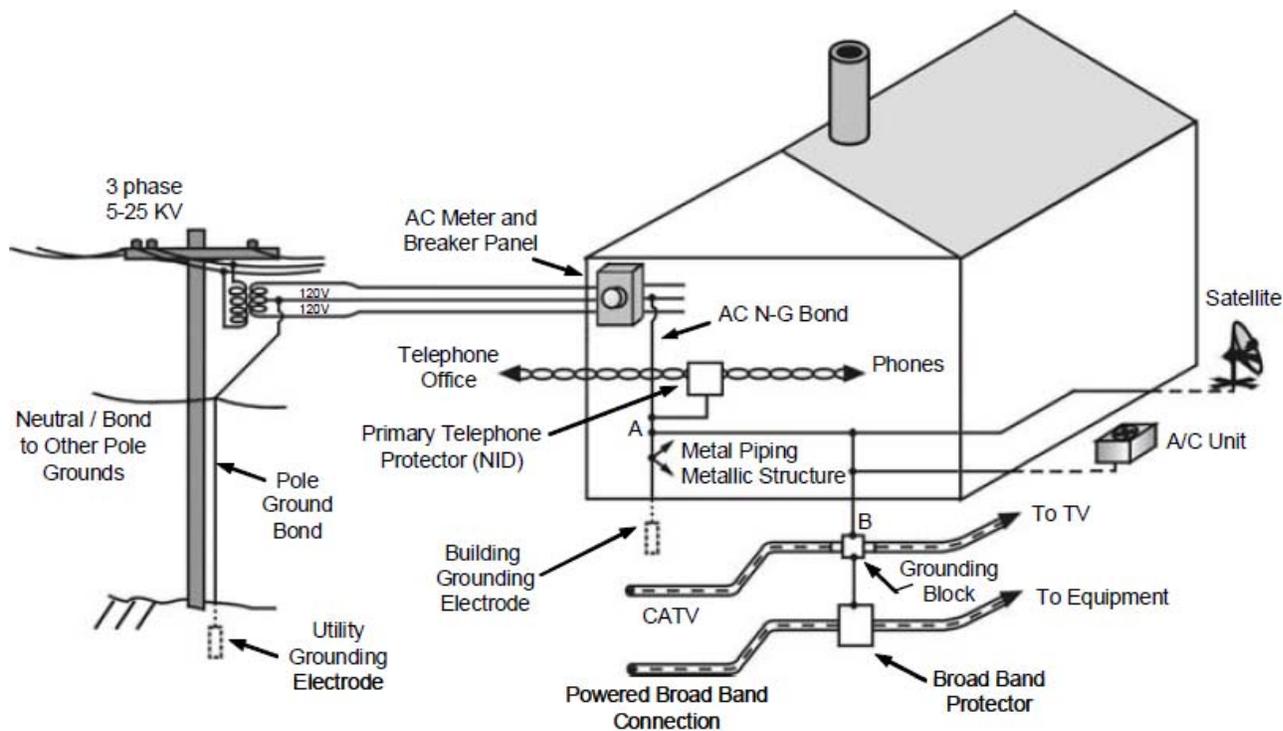


Figure 3: Basic Grounding and Protection Required by 2002 NEC<sup>5</sup>

### 3.5 Multiple Buildings

Some homes have outlying buildings such as a pool house or a gazebo that have electrical or communications wiring running between the main building and the outlying building(s). All of the above recommendations should be followed for the outlying buildings as well. Furthermore the grounding electrode system for each building must be bonded to each other. Otherwise a lightning strike can raise the potential of the grounding system of one building relative to the other by hundreds or even thousands of volts for a short period of time resulting in damage to any connected equipment.

## 4. Wiring

For the purposes of this Guide, we will consider two basic types of wiring in buildings – line voltage (120 volt or 240 volt wiring used to supply electric power), and low voltage (Ethernet, cable/satellite TV, telephone, security, controls, etc.) Do not confuse “low voltage” as it is used here with low voltage as used by utilities or in the NEC. Low voltage for the purposes of this guide generally means less than 50 volts. The line voltage wiring and devices should be installed by a professional electrician knowledgeable in the NEC and local codes which can differ depending on location. However, many installers of low voltage cabling including do not understand the

<sup>5</sup> IEEE How to Protect Your House and Its Contents from Lightning  
[http://www.lightningsafety.com/nlsi\\_lhm/IEEE\\_Guide.pdf](http://www.lightningsafety.com/nlsi_lhm/IEEE_Guide.pdf)

regulations surrounding its installation. Additionally even when installed according to code, line voltage wiring can cause EMC and EMI issues. In particular, electronic lighting dimmers and dimming systems, and many florescent ballasts generate a great deal of electromagnetic interference that can result in EMC and EMI issues.

#### 4.1 Low Voltage Security, Audio, Video, Controls, and Telecommunications Wiring

The NEC in general sets a minimum separation of 2 inches between communications and electric power cabling unless there is a physical barrier between them such as a raceway (1996 NEC article 800-52). There are other exceptions allowed such as when all of the power conductors “are in a metallic-sheathed, metallic clad, non-metallic sheathed, type AC, or type UF cable” (exception 1 of NEC article 800-52). However, the NEC is focused on safety issues such as shock and fire, not EMC.

To ensure your Smart Grid and other connected devices operate reliably requires more than is required by the NEC. TIA 570B and Building Industry Consulting Services International (BICSI) Telecommunications Distribution Methods Manual (TDM) go into much more detail as to the separation of different types of low voltage cabling from electrical power and from other types of low voltage cables.

***NOTE: When any of the following recommendations conflict with NEC, state and/or local codes, the minimum applicable code must be met.***

##### 4.1.1 General Considerations

- Never run communications or other low voltage wiring through conduit containing electric power conductors or through the same bore hole (hole drilled through walls, floors, support structures, etc.) used for electric power conductors.
- The NEC requires protection to be installed at the building entrance for telephone cables (NEC 70 article 800), CATV/antenna/satellite coaxial cables (NEC 70 articles 810 and 820), and broadband cables which carry power (NEC 70 article 830). Your phone, satellite or cable company should have ensured the lines entering your home have been properly protected when they were installed (figure 3).
- All other cabling including security, controls, “invisible dog fences”, etc. must be installed according to manufacturer’s instructions including grounding any metallic conduit they are installed in, cable shielding,

etc. They should also have surge protection at the entrance to the home.

#### 4.1.2 Unshielded Twisted Pair (UTP) for voice, data and video (TIA 570B section 6.1.4.1).

- Required separation from electric power conductors: **2 inches**
- Recommend separate from power conductors for parallel runs: **6 inches** or greater. BICSI's TDM recommends 24 inches separation where possible.
- Where it must cross power conductors, it should do so at right angles.
- Recommended separation from other low voltage wiring for parallel runs: **6 inches**
- UTP used for Ethernet networks must be no longer than 100 meters in total length – 90 meters maximum for any single run and 10 meters maximum to connect equipment to the Ethernet jack.
- When installing UTP be certain not to bend the cable sharply. "In spaces with UTP terminations, cable bend radii shall not be less than four times the cable diameter" (TIA 570B section 6.2.1).
- Caution should also be observed when pulling the cable as it is easily damaged. TIA 570B section 6.2.2 recommends the maximum pulling tension not to exceed 25 pound-feet.
- When terminating UTP, always follow the manufacturers' instructions or TIA 570B section 6.2.3.
- UTP runs longer than 90 meters, bending it sharply, poor termination, or damaging it when installing it can result in decreased network speeds and increased error rates.
- Always leave at least 8 inches of extra UTP cable coiled within the wall outlet.

#### 4.1.3 Security Systems (TIA 570B section 6.1.4.2)

- Required separation from electric power conductors: **2 inches**

- Recommended separation from electric power conductors for parallel runs: **6 inches**
- Recommended separation from other low voltage circuits for parallel runs: **6 inches**.
- Where it must cross power conductors, it should do so at right angles.

#### 4.1.4 Whole-home audio systems (TIA 570B section 6.1.4.3)

Audio cables are particularly susceptible to EMI from both electric power and low voltage cabling. Extra care should be taken to ensure these cables maintain adequate separation to avoid induced noise.

- Required separation from electrical power conductors: **2 inches**
- Recommended separation from electrical power conductors for parallel runs: **12 inches** minimum
- Where audio system cabling crosses power cable, it should cross at a right angle.
- Separation from other telecommunications cables: **12 inches** minimum to minimize induced electrical interference problems.
- Where audio system cabling crosses other telecommunications cabling, it should cross at a right angle.

#### 4.1.5 Coaxial Cables (Cable and Satellite TV): NEC article 820-52

- It is highly recommended that all installations use RG6 cable. RG59 (often used in older installations) is inadequate for today's cable, satellite and cable Internet technology.
- At the point where the cable enters the home (passes from the outside wall into the home), the outer conductive shield/braid/foil must be grounded via an insulated grounding conductor not less than 14 AWG to the grounding electrode (NEC articles 820-33, 820-40). This is done using a grounding block.
- Required separation distance from electrical power: **2 inches**
- Recommended separation from electrical power conductors for parallel runs: **6 inches**

- Where coaxial cabling crosses electrical power conductors, it should cross at a right angle.
- “The minimum bend radius for coaxial cable shall not be less than recommended by the manufacturer. If no recommendation is provided, the minimum bend radius shall be 10 times the cable outside diameter under no-load conditions and 20 times the cable outside diameter when the cable is under a tensile load” (TIA 570B section 6.3.1).
- “The maximum pulling tension of coaxial is dependent on the size and material of the center conductor. Copper-coated steel (CCS) is stronger than bare copper. Pulling tension should not exceed 150 lbf for CCS and 80 lbf for copper” (TIA 570 section 6.3.2).
- When terminating (attaching the “F” connector) a coax cable, always follow the manufacturers’ instructions carefully. Improper termination including improper termination of the grounding braid or foil can result in poor performance and electromagnetic interference to other equipment.

## 5. Surge Protection Devices (SPDs)/Transient Voltage Surge Suppressors (TVSS)

Regardless of the building protection used, lightning strikes on the building, grounds and objects surrounding the building or wiring entering or leaving the building, as well as voltages induced on above ground wiring entering the home can still cause damage to unprotected equipment and systems due to high surge energy and fast transients. Additionally there are many things within the home that can cause lower energy surges and fast transient events including some types of furnaces, electric power tools, vacuum cleaners, welders, and even opening a circuit breaker. To protect against this it is recommended that residential buildings include surge protection on all wires entering or leaving the building, on all electrical subpanels, and at outlets supplying electronic devices that are sensitive to surges and fast transients.

SPDs and TVSS protect equipment from overvoltage conditions that can arise from surges and fast transients. They typically use devices such as metal oxide varistors (MOVs) that operate by clamping over voltages when a high voltage occurs between the wires they are connected to. However, MOVs operate too slowly for some very short events – on the order of nanoseconds. To protect against fast transients some TVSS also include fast acting diodes and filters.

It is important to protect not only electric power conductors entering or leaving the building but the

low voltage telecommunications, cable or satellite TV, control, and A/V wiring as well. Even when these wires are buried underground they can be subjected to high energy pulses from lightning. Once on the wiring the surge energy is conducted along the wiring to connected equipment. From there it can jump across traces and travel along other conductive paths such as an Ethernet cable to additional equipment. A single lightning strike on a telephone wire, cable or satellite TV cable, wiring to an outdoor security camera, a pool heater control cable, etc., can therefore destroy all of the equipment within a home even when they are connected on different networks.

Finally, MOVs have a limited life depending on the number of surges they experience and the amount of energy of the surges. While they are designed for an expected life of 20 years or more a single or several high energy surges can destroy them. For this reason most high quality SPDs include an LED or audible indicator to let you know when they are operational (typically LED lit means it is good). It is highly recommended that all SPDs, including hardwired and plug-in versions, include an indicator. If the device is not normally visible, an audible indicator is also recommended.

### 5.1 Types of SPDs

There are 3 main types of SPDs for protection of line voltage wiring, each characterized by the types of surges they protect against and the amount of energy they can dissipate.

#### 5.1.1 Type 1 – Secondary Surge Arrester

“Type 1 SPDs are generally intended to be installed on the line side of the main service disconnect overcurrent device. Their main purpose is to protect insulation levels of the electrical system.”<sup>6</sup>

Also called lightning surge arrestors or secondary surge arresters, these are used to protect against high energy surges such as direct lightning strikes. Type 1 SPDs are primarily used in commercial and industrial buildings. They are installed at the service entrance to the building on the line side (utility side) of the main service disconnect (the main breaker) – either at the meter or at the main electrical service cabinet (circuit breaker cabinet).

Unless your home is prone to direct lightning strikes and has building protection installed, a Type 1 SPD is probably not required.

***Type 1 SPDs should ONLY be installed by a professional electrician. They are installed either at the meter or between the meter and the main disconnect and therefore the only way to disconnect power is to remove the meter which must be done by your utility.***

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<sup>6</sup> National Electrical Manufacturers Association Frequently Asked Questions <http://www.nemasurge.com/help.html>

### 5.1.2 Type 2 – Transient Voltage Surge Suppressors

“A permanently connected SPD intended for installation on the load side of the service disconnect overcurrent device, including SPDs located at the branch panel.”<sup>7</sup>

Type 2 TVSS surge suppressors are the main protection for indirect lightning strikes. These are installed on the load side of the service entrance panel (after the main circuit breaker) and on all subpanels (larger homes may have more than one electrical panel). When a Type 1 SPD is installed on the main service entrance panel, Type 2 SPDs should be used on the subpanels. A type 2 SPD will not protect against a direct lightning strike.

As with Type 1 SPDs, they typically are installed from L-N. However, when installed in a subpanel it is recommended that the device include N-G protection as well since the neutral conductor is only bonded to ground at the service entrance which may be some distance from the subpanel.

### 5.1.3 Type 3 – Point of Use TVSS

“Point of utilization SPDs, installed at a minimum conductor length of 10 meters (30 feet) from the electrical service panel; e.g. cord connected, direct plug-in, receptacle type SPDs installed at the utilization equipment being protected. The distance (10 meters) is exclusive of the conductors provided with or used to attach the SPD.”<sup>8</sup>

A type 3 SPD is only capable of dissipating low energy surges and should be used in conjunction with Type 1 and/or Type 2 SPDs. Surge strips and outlet surge protectors are typically Type 3. It is highly recommended that any Type 3 SPDs include fast transient protection. These cost more but provide far better protection than do the inexpensive MOV only models.

### 5.1.4 Phone/DATA/CATV/Control Bus Surge Suppression

Your phone, cable or satellite TV, security system, gate, pool heater and pump controls, and any other wiring entering or leaving your home should be protected from surges as well. Even if these are run underground into the home they are subject to surges induced by ground strikes in the area.

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<sup>7</sup> National Electrical Manufacturers Association Frequently Asked Questions <http://www.nemasurge.com/help.html>

<sup>8</sup> National Electrical Manufacturers Association Frequently Asked Questions <http://www.nemasurge.com/help.html>

Smart Grid devices are likely to be installed on more than one network. For example, the meter may connect to a gateway via a powerline carrier network. The gateway in turn may have an Internet connection over Ethernet as well as wireless networking such as ZigBee or WiFi either built in or connected to it over Ethernet. More sophisticated systems may also include RS232 controls. A single surge can jump across traces on the gateway's printed circuit board or elsewhere and damage any and all connected devices that have a wired connection. By clamping the voltage at the entrance to your home the chance of damage is minimized.

It is also recommended to install "point of use" surge protection (plug-in, surge strips, or receptacle surge protectors) for the data, CATV, and other low voltage connections to your gateway, computer, TVs, routers, and cable or DSL modems. These devices are extremely sensitive to surges including those generated within your home.

## 5.2 Installation of SPDs

Type 1 and Type 2 SPDs should only be installed by a qualified electrician due to the risk of electrical shock, the potential for fire if incorrectly installed, and variations in state and local code. Additionally, all manufacturers' installation instructions must be followed closely due to the many configurations these devices come in.

### 5.2.1 Installing Type 1 Surge Arrestors

Type 1 SPDs are installed on the line side of the service entrance as close to the circuit breaker cabinet as possible. The reason is that due to the extreme currents resulting from lightning strikes every foot of wiring can add 200 - 300 volt rise in let through voltage due to the voltage drop across the wires used to connect them. This means that ALL of the connections to the SPD must be kept short – phase, neutral, and ground. The conductors should be installed as straight as possible, i.e. no sharp bends.

When Type 1 SPDs are used on the main service panel it is highly recommended that a Type 2 SPD also be installed. This is because the higher energy capability of Type 1 SPDs will allow voltages high enough to still cause damage to electronic equipment in the home. Type 2 SPDs typically have a lower clamping voltage.

Care must be taken when installing both Type 1 and Type 2 SPDs together. It is necessary to separate them by at least 10 meters/30 feet of wiring between them. If that is not possible many commercially available devices

combine Type 1 and Type 2 in a single enclosure.

Type 1 SPDs must be installed on the line side of the main panel. Therefore they cannot be used on subpanels.

### 5.2.2 Installing Type 2 TVSS

Type 2 TVSS devices may be installed at the service entrance on the load side of the service disconnect (see Figure 4) when the risk of direct lightning strikes is low, and on subpanels. Since Type 2 SPDs are installed on the load side of the service disconnect, each phase independently protected by a circuit breaker or a fuse. As with Type 1 SPDs they should be installed with the shortest conductors possible to minimize the let-through voltage.

When installed on subpanels with a Type 1 SPD installed on the main panel the Type 2 SPD must be installed with a minimum conductor length of 10 meters (30 feet) between it and the Type 1 SPD. If that is not possible many commercially available devices combine Type 1 and Type 2 in a single enclosure.

As with Type 1 SPDs, the conductors should be installed as straight as possible, i.e. no sharp bends.

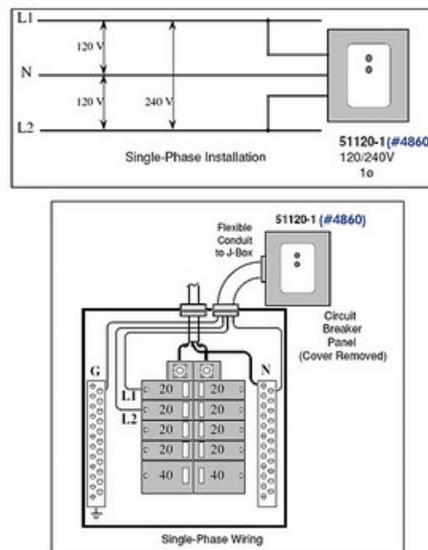


Figure 4: Typical Installation of a Type 2 SPD (Courtesy of Leviton Manufacturing)

### 5.2.3 Installing Type 3 SPDs

Type 3 point-of-use SPDs come in 3 basic configurations

- Receptacle (hard wired receptacle replaces wall receptacle)
- Plug-in style (no connecting cord)
- Cord connected plug strips

The choice of which one to use is up to the homeowner.

Additionally point-of-use TVSS devices come with various features including

- Basic (power surge suppression only)
- Power surge suppression plus fast transient suppression
- Power surge suppression plus data/CATV protection (with or without fast transient suppression)

Here the choice should be made based on the application. For example a location that includes multiple devices such as a desk with a computer, gateway, router, etc. and that includes both data and power should use an SPD that includes data protection whereas a TV might use a power surge plug-in device with CATV surge protection.

As with 120/240 volt SPDs, low voltage surge suppression installed at the entrance to the home and on distribution panels require short conductors to ensure low clamping voltage. The low voltage distribution panel should be located within 5 feet of a dedicated, grounded, non-switchable, duplex outlet. This is for two reasons. First, if there are any active devices required such as a CATV amplifier, router, etc., you will need power. Second, the TVSS devices used to protect your CATV, phone, and other low voltage wires entering the building will need a good connection to the building's ground. Use of a surge receptacle outlet is recommended.

Point-of-use surge suppression requires no special installation. Simply follow the manufacturers' instructions and be sure to replace it if the LED or audible alarm indicates it no longer is providing protection.

***NOTE: the line voltage TVSS and the low voltage TVSS should be plugged into the same receptacle or surge strip to ensure they share the same ground connection.*** If different ground connections are used a high voltage

can develop during a surge or fast transient event resulting in damage. Use of combined line/low voltage point of use TVSS eliminates this problem.

### 5.3 Summary of National Electric Code Requirements for SPDs<sup>9</sup>

Connecting an SPD to the electrical distribution must be accomplished in accordance with the National Electric Code and all local codes. The primary requirements for connecting an SPD in accordance to the National Electric Code are:

- Article 285.3 – SPDs shall not be used on ungrounded, impedance grounded, or corner-grounded systems unless approved for use
- Article 285.4 – Where used, SPDs shall be connected to each ungrounded (line and neutral) conductor
- Article 285.5 – SPDs shall be Listed
- Article 285.6 – SPDs shall be marked with a short circuit current rating (SCCR), and shall not be installed at a point on the system where the available fault current exceeds the SCCR of the SPD
- Article 285.11 – SPDs can be connected indoors or outdoors, and shall be inaccessible to unqualified persons
- Article 285.12 – Conductors used to connect the SPD to the system shall be as short as possible
- Article 285.26 – Conductors used to connect the SPD to the system shall be greater than 14 AWG copper, or 12 AWG aluminum
- Article 285.27 – SPDs shall be permitted to be connected between any two conductors of the system: grounded, ungrounded, or grounding conductors; connection of the grounded and grounding conductors shall only be interconnected during a surge

## 6. Wireless Networks

There are numerous types of standards based wireless local area networks (wLAN) in use today including WiFi (802.11a, b, g, n), ZigBee (IEEE 802.15.4), and Bluetooth (IEEE 802.15.1) along with a host of proprietary networks and access networks (cellular/3G/4G). Two things they all have in common are:

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<sup>9</sup> Transient Protection Of The SMART Grid: An AC Power Perspective – October 2010  
[http://emersonnetworkpower.com/en-US/Brands/SurgeProtection/Documents/White%20Papers/WP-30018\\_SmartGridSPDs\\_rev0\\_10-10.pdf](http://emersonnetworkpower.com/en-US/Brands/SurgeProtection/Documents/White%20Papers/WP-30018_SmartGridSPDs_rev0_10-10.pdf)

- 1) They can be interfered with by any device that emits radio frequency (RF) electromagnetic energy including other WLAN devices and
- 2) They all emit RF energy that can interfere with other devices including WLAN devices and non-RF devices.

#### 6.1 Causes of Interference to WLANs

There are numerous sources of EMI to WLANs including microwave ovens, cordless phones, Bluetooth devices, wireless video cameras, baby monitors, outdoor microwave links, wireless game controllers, Zigbee devices, fluorescent lights, as well as other WLANs operating in the same frequency bands.

##### 6.1.1 Co-channel Interference

When WLANs interfere with each other it is called co-channel interference. For example ZigBee, WiFi 802.11b/g and many 802.11n devices as well as Bluetooth devices all operate in the same 2.4 GHz band. While these networks are designed to coexist with each other and even work to avoid each other's transmissions, as more of these devices are added in proximity to each other congestion will inevitably lead to reduced bandwidth. There are several strategies that can minimize these problems

- **Frequency diversity**  
Many Smart Grid installations will use ZigBee to connect the SG meter to other Smart Grid devices in the home. ZigBee devices operate a low power and therefore are easily interfered with by other devices operating at 2.4 GHz. "Dual Band" IEEE 802.11n devices can operate at both 2.4 GHz and 5GHz. The 5GHz band is less congested than 2.4 GHz and also has more spectrum allowing more data channels to be used. This means both your ZigBee and WiFi N (when operating in the 5 GHz band) will have better throughput. A side benefit is that there are far fewer WiFi devices and cordless phones in the 5GHz band. Additionally microwave ovens operate near the 2.4 GHz band so they will not cause interference to your WLAN either.
- **Minimize the number of non-WLAN devices that operate at the same frequency as your WLANs.** In particular, try to avoid cordless phones, baby monitors (video and/or audio), RF remote controls, and other wireless devices that operate in ZigBee's 2.4GHz frequency band.
- **Spatial Diversity**  
Try to separate WLAN including ZigBee devices from other RF devices as

much as possible, especially if they are operating in the same frequency bands. RF power falls off as a square of the distance between them. Therefore doubling the distance between 2 devices cuts the risk of interference by a factor of 4.

ZigBee is a mesh network. This means that if, for example, the ZigBee SG meter cannot talk directly to your ZigBee enabled refrigerator, a ZigBee device located between them will act as a repeater of sorts for the data packets. Thus if you have no connection or an intermittent connection between two ZigBee devices you can simply add another between them. Any plug-in ZigBee device will do the job.

For plug-in ZigBee devices, sometimes simply moving the device to another outlet either further from the interfering device or closer to the ZigBee device it needs to communicate with will fix the problem.

#### 6.1.2 Out of Band Interference

Some RF transmitters such as baby monitors, video repeaters, etc., can affect devices even when they operate at in different bands. This can be a more difficult problem to troubleshoot. Try turning on and off or unplugging different devices until you find the offending device. Once you locate it you can moving things around (if possible) to improve the situation.

#### 6.1.3 Unintentional Emitters

While the FCC regulates the emissions of most devices that might interfere with wLANs, the levels can still be too high when in close proximity to a wireless receiver. Florescent ballasts, power supplies, and many other devices may turn out to be the culprit. Also, sometimes a device can “go bad”. A defective florescent ballast can generate broadband RF interference that can cause interference even when it is not close to the wireless receiver. Try moving the device to a different outlet (even a few feet can make a difference) or turning various devices on and off to see if it makes a difference.

#### 6.1.4 Structural Issues

Large mirrors, foil wall paper, large appliances, wire mesh lathing (used in older homes with plaster walls), metal fences (for outdoor applications) and other metallic objects located between wireless devices can greatly

attenuate the RF signal causing poor performance or blocking the signal entirely. Try to locate your wireless devices in places where these objects are not in the “line-of-sight” (this does not mean you have to be able to see the device. It means that if you drew a line between them through walls, furniture, etc. they would lie along the line). If this is not possible you may have to add an additional ZigBee device in a location with line-of-sight to both devices. The same thing can be done with WiFi devices by adding an additional wireless router.

#### 6.1.5 Improving the Signal

Some WLAN devices come in different models that operate at higher power, have more antennas, or higher gain antennas. One feature that has become popular with WiFi devices is called MIMO or Multiple Input/Multiple Output. MIMO does not operate by increasing the power being transmitted. Instead it provides additional paths for the signal improving the signal to noise ratio. In general more antennas are better. If you are having trouble with your WLAN, you can look to purchase a better grade of Access Point/Router that includes MIMO technology. This will help to overcome both in-band and out of band issues.

There are also higher gain antennas available for WiFi and other wireless devices. The use of these is not recommended. The device has been tested to pass the FCC’s testing. Changing the antenna will likely result in a violation of FCC regulations and may result in interference to your other devices or those of your neighbors.

## 7. Powerline Carrier Networks

Powerline carrier (PLC) networks use an RF signal transmitted over the home’s electrical power lines. There are several types of PLC networks for use in the home.

- 1) Wideband PLC (used for both controls and as a replacement for Ethernet and high speed networks)
- 2) Narrowband PLC for use in homes (typically used for controls)

### 7.1 Wideband PLC

Operating at frequencies from 2 MHz up to 50 MHz or higher over the power lines in your home, wideband PLC has gained popularity in recent years as an alternative to Ethernet and WiFi for broadband distribution, gaming, and video distribution. The most well-known

version is called HomePlug™ which is one of several technologies specified in a new standard, IEEE P1901 and developed with the Smart Grid in mind. However several broadband PLC technologies are available although not all can communicate with each other. Therefore make certain when purchasing PLC products that they are certified to interoperate with each other.

### 7.1.1 Problems With Your PLC Network

- Separate 120v lines

Many homes are supplied by two 120 volt lines. Together they provide the 240 volts needed to power electric dryers, ovens and stoves, and other devices. However, there is no permanent connection between the two phases. Therefore a device plugged into one outlet may not talk to another if the second one is plugged into a receptacle fed from the other 120 volt line. In many homes there is enough cross-talk within the circuit breaker box and wiring to enable them to communicate. However if the distances are substantial or there are noisy power supplies or other devices on the line the link may be slow, incur high error rates or even fail to connect. The simple solution is to try plugging the device into different outlets until it works.

An alternative, especially if your building has more than one circuit breaker box, is to connect one device to a power outlet located on each of the circuit breaker boxes or each of the circuits. Then connect an Ethernet cable between each of the PLC devices to link the different circuits together.

- Surge Suppressors

Some surge suppressors, especially point-of-use TVSS devices, contain filters for fast transients. While this is great for protection against these transients, they can filter the signal degrading it or even completely eliminating it. A quick test is to plug the PLC device directly into the wall outlet. If it works, you can either leave it without surge protection or check the manufacturer's instructions or Web site for compatible surge protection devices.

- Conducted Noise

Many power supplies built into computers, TVs, microwaves, and other devices conduct electromagnetic "noise" onto the power lines. Even when they are within FCC limits, if they are plugged in close to the PLC device they may degrade the signal enough to limit throughput or

cause unacceptable error rates.

To remedy this unplug various devices near or plugged into the same outlet as your PLC devices to determine which device(s) are causing the problem. Then plug the offending device into a separate wall outlet away from the PLC device. Now the problem: If you identify an offending that is also connected to the PLC device via for example Ethernet, how do you ensure a common ground for surge protection? First try connecting the PLC device directly into one wall outlet and use a plug in surge strip for the rest of the devices. You can also try using connecting the offending device(s) using an extension cord. Finally if all else fails, use different receptacles (but you still want to use surge protection).

***NOTE: Air conditioners, refrigerators and other high current devices should not use extension cords unless specifically rated for that use. An underrated extension cord will cause them to run inefficiently, potentially fail prematurely, and risk fire from an overloaded extension cord.***

Some florescent ballasts and electronic lighting dimmers can also degrade performance. PLC devices should not be operated on the same circuits. If the problem is a florescent ballast, check to make certain the ballast is not defective. If it is not, try moving the PLC device to another receptacle.

#### 7.1.2 Issues Caused by PLC Networks

There have been some problems seen in the field that are caused by wideband PLC networks. These include

- Touch dimmers that turn on/off or change dimming levels in the presence of PLC networks.  
If a device that had been working normally prior to installing the PLC network starts to malfunction, try moving one of the devices to other outlets until the problem goes away.
- GFCI Tripping  
PLC devices should not be plugged into a GFCI outlet or an outlet protected by a GFCI circuit breaker. If the outlet you have plugged it into is causing a GFCI breaker or a GFCI outlet to trip, chances are it is

protected by that GFCI and should be moved to another outlet.

### 7.2 Narrowband PLC

Narrowband PC, typically operating below 500 kHz, is used mainly for low throughput applications such as lighting controls or turning power on and off to a device. It is seen as a potentially useful solution for the SG since many of the applications will only require low bit rates. Many of the same issues seen in wideband PLC exist with narrowband PLC as well. However, due to its lower operating frequencies and bit rates they are not as prevalent. Of course due to its lower data rate it is not useful for high through applications such as broadband and video.

If problems occur, see the solutions identified under wideband PLC.

### 7.3 Broadband Powerline Carrier Networks (BPL)

BPL is primarily a utility solution over their transmission networks and potentially to the SG meter. Therefore it is not covered in this guide. However, there have been reports of meters using utility Broadband Powerline Carrier (BPL) networks incurring high error rates or failing to operate reliably in the presence of some PLC networks. The reverse may be true as well. If moving the in-home PLC device to other outlets does not solve the problem, you should contact your local utility.

## 8. References

The following are a list of good references for home owners interested in learning more about this subject.

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