



**Asia-Pacific  
Economic Cooperation**

# Rooftop Solar PV System Designers and Installers

## Training Curriculum

APEC Secretariat

March 2015

# ELECTRICAL WORKMANSHIP

*Training of PV Designer and Installer*



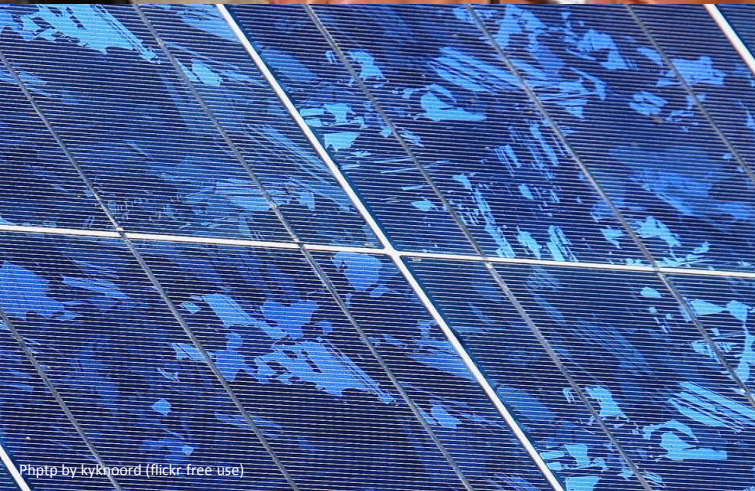
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**International Copper  
Association**  
Copper Alliance



**castlerock**  
consulting



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- A. Introduction
- B. Cable sizing
- C. Drip loop
- D. Surge protection
- E. Lightning protection
- F. Grounding
- G. Other common issues (checklist)



# A. Cable Sizing



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**Residential fires that are caused by electricity occur more than 40,000 times each year all over the world**

**Over \$700 million in property damage**

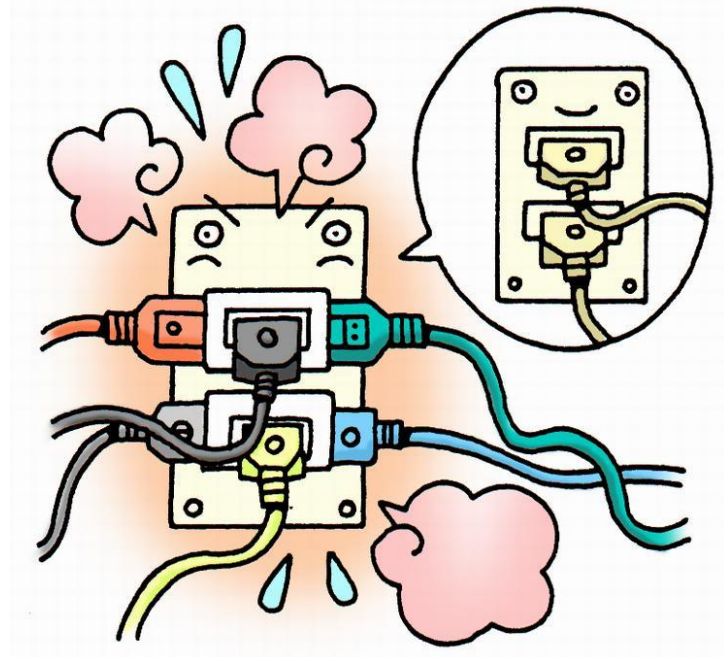


# A. Cable Sizing

Overloaded wires are one of the reasons for electrical system failures. While the wiring may be up to code, but multiple extension cords and circuit splitters can overload the wires with too much current.



Photo credit: [www.agentknowhow.com](http://www.agentknowhow.com)



[http://www.city.funabashi.chiba.jp/kurashi/shoubou/0009/konsento\\_d/img/002.jpg](http://www.city.funabashi.chiba.jp/kurashi/shoubou/0009/konsento_d/img/002.jpg)



# B. Drip Loop

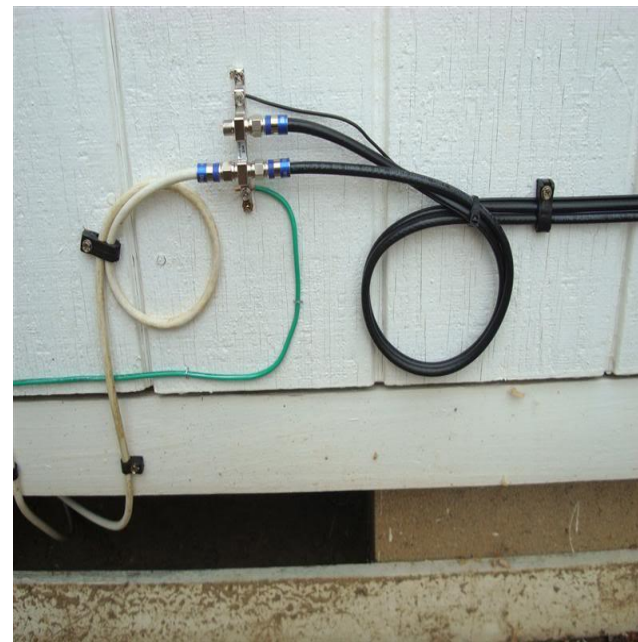
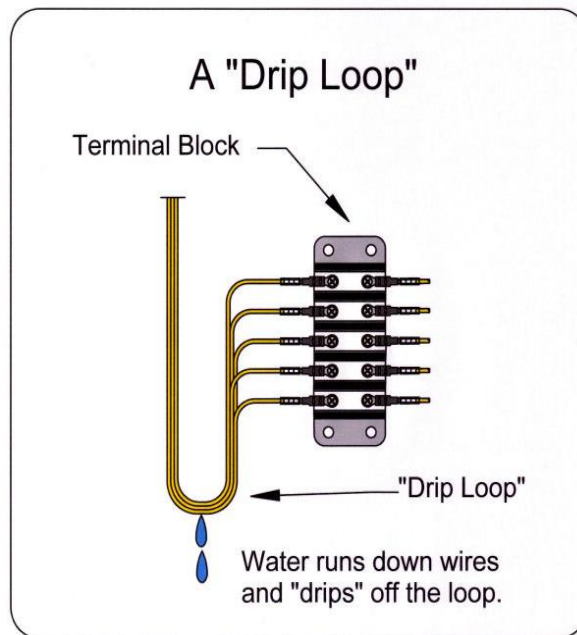
- What is a Drip Loop?



# B. Drip Loop

- **What is a Drip Loop?**

An electrical service drip loop is a loop formed on the incoming feeder wires of your electrical service, before the meter. The overhead wires come to your service pole via the utility company.



# B. Drip Loop

- What Purpose Does It Serve?





# B. Drip Loop

- **What Purpose Does It Serve?**

To allow any rain or moisture, that may make contact with the wires to drip off. Water or moisture running down the service pipe or into electrical connection points can cause serious damage or even fire.

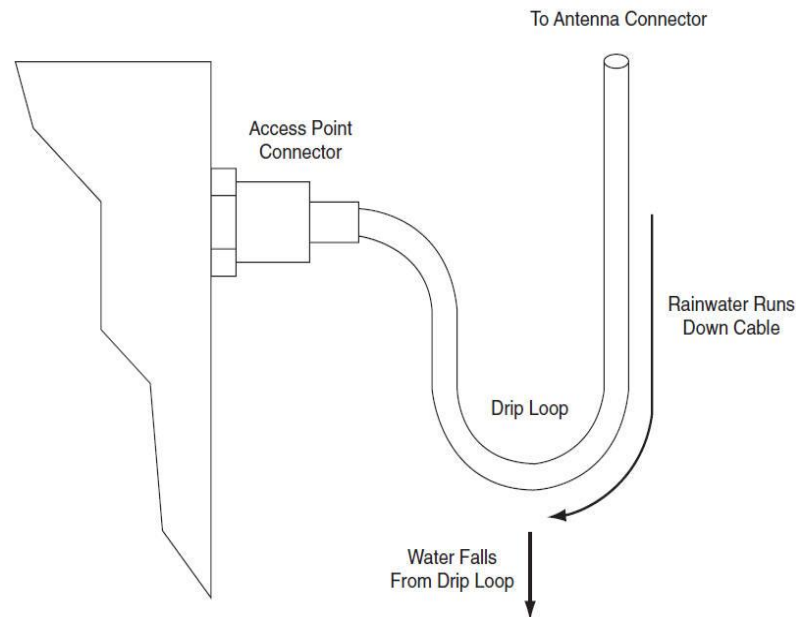


FIGURE 8-20: Diagram of a drip loop.

# C. Surge Protection

- What is surge protection



# C. Surge Protection

- What is surge protection

A surge protection device (SPD) is used to provide a discharge path to earth for high voltage transients caused by direct or indirect effects of lightning (or other power system anomalies). It is NOT used to direct the full power of a lightning strike to ground



# C. Surge Protection

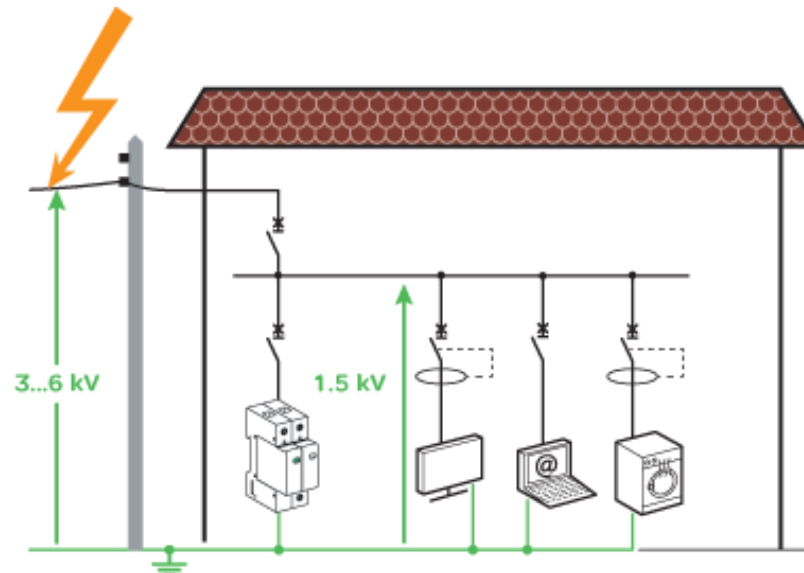
- Is it to protect your equipment from lightning?



# C. Surge Protection Devices



- Is it to protect your equipment from lightning?  
A true lightning protection use devices such as air terminals with a proper down conductor and grounding rod, equipotential bonding for all current carrying components and proper grounding principles. But these devices still do not prevent electromagnetically induced transient voltages. Only SPDs can protect against this.



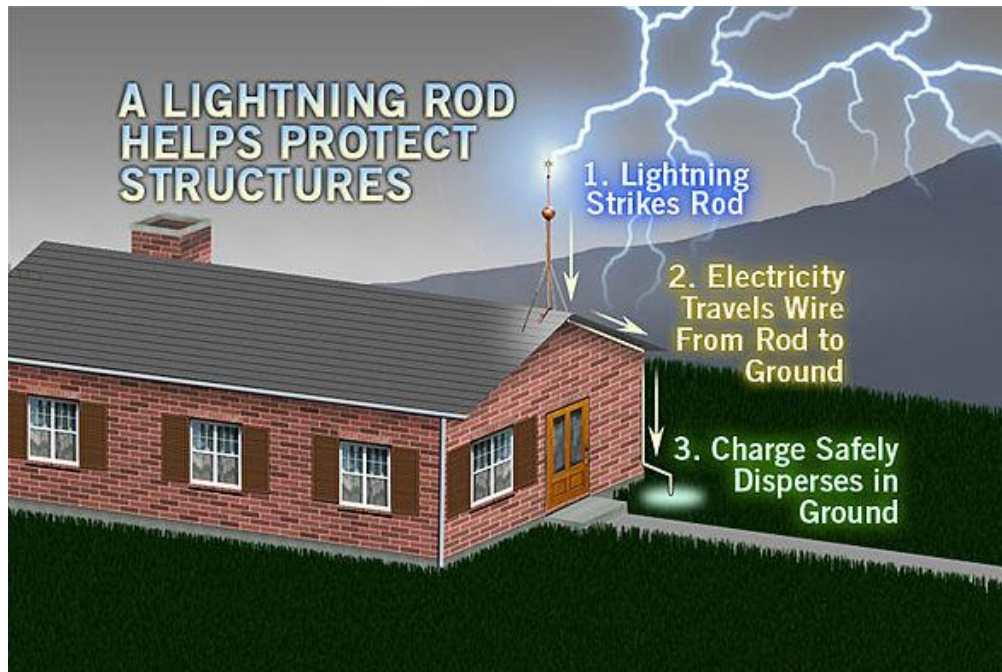
# D. Lightning Protection

- What is lightning protection?



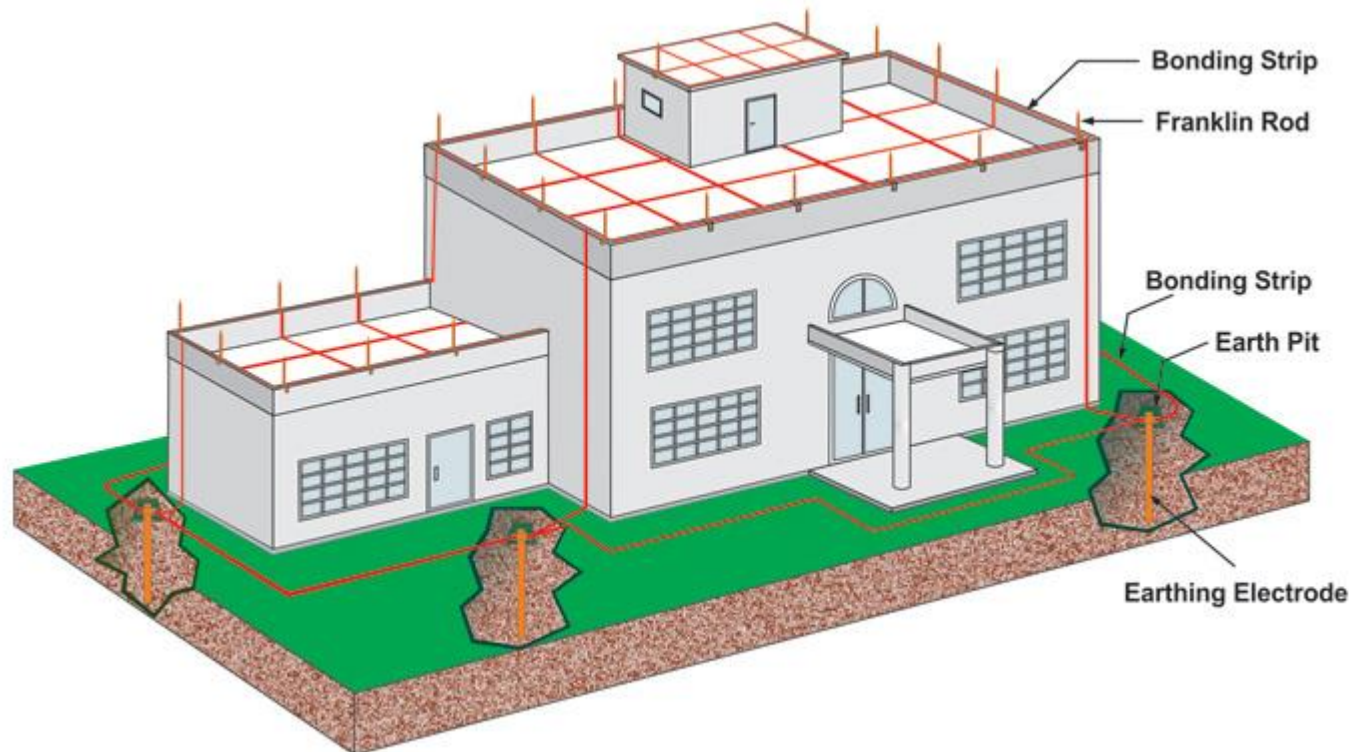
# D. Lightning Protection

- What is lightning protection?  
A system designed to protect a structure from damage due to lightning strikes by intercepting strikes and safely passing extremely high currents to ground.



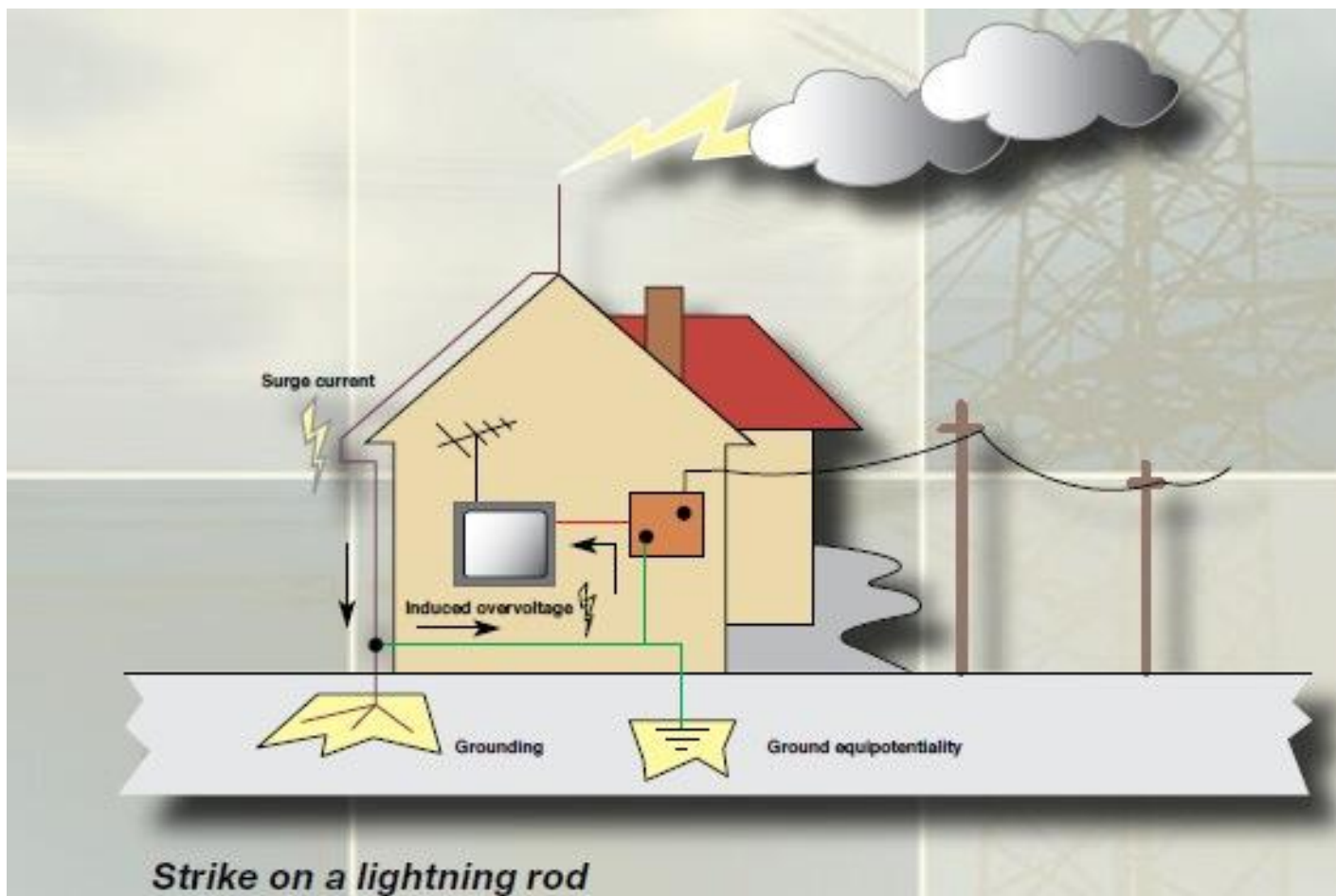
# D. Lightning Protection

A lightning protection system includes a network of air terminals, bonding conductors, and ground electrodes designed to provide a low impedance path to ground.





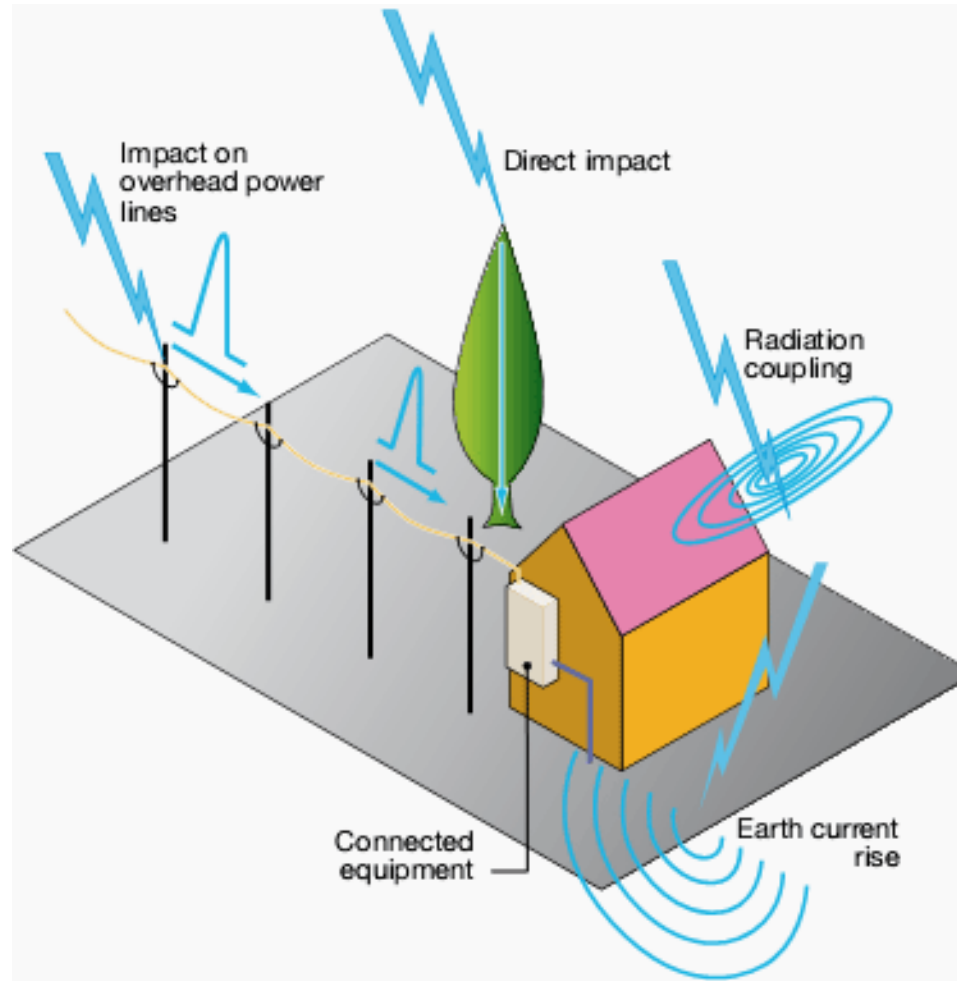
# D. Lightning Protection



<http://electrical-engineering-portal.com/overvoltages-caused-by-lightning>



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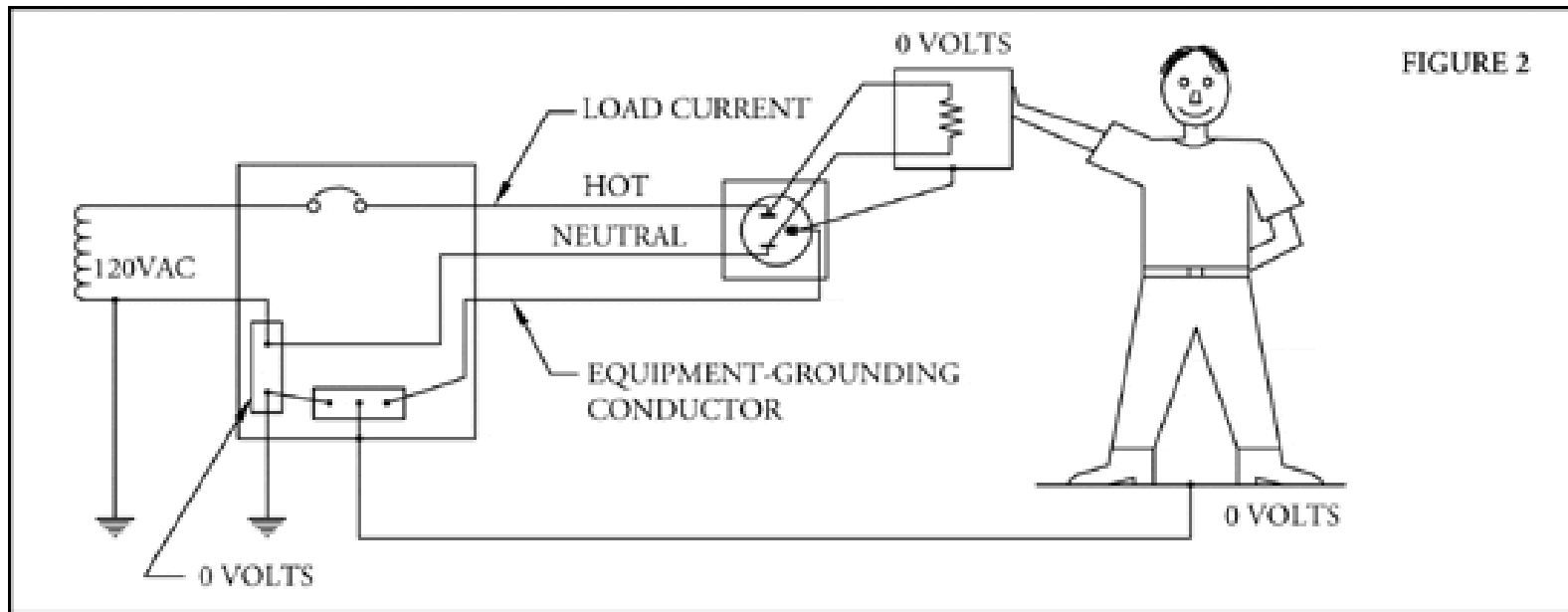


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# E. Grounding

- A grounding system needs to be designed with personnel and equipment safety in mind

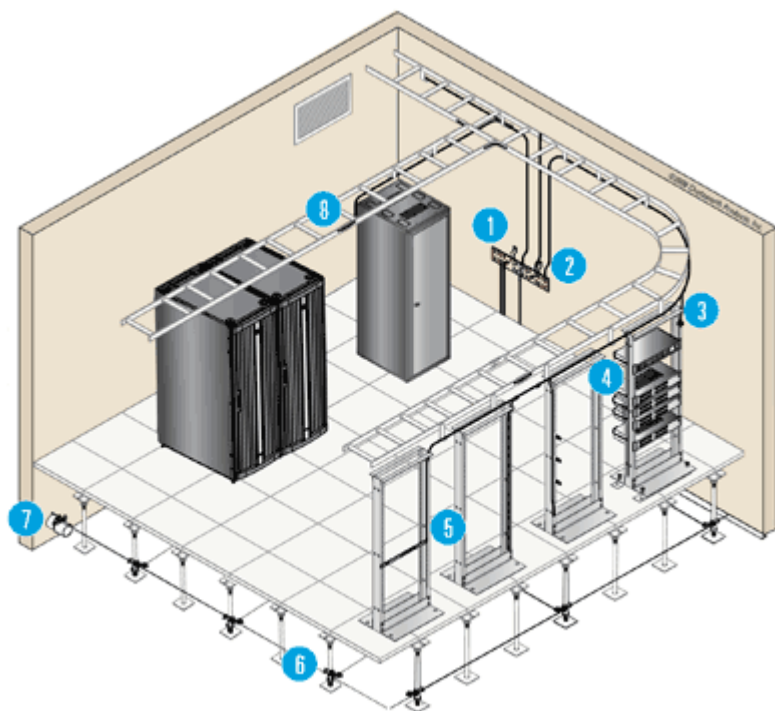


[www.epgco.com/equipment-grounding.html](http://www.epgco.com/equipment-grounding.html)



# E. Grounding

- Other uses for a grounding system is as a signal reference and to provide a mean to clear system faults in some equipment types



1. **Grounding busbar:** Provides a central ground attachment point for equipment located in the data center or equipment room.
2. **Compression lugs and taps:** Connect copper or tinned copper conductors to busbars, racks, cabinets, cable runways or other conductors.
3. **Two-mounting hole ground terminal block:** Provides a convenient way to attach ground wires to racks or cabinets.
4. **Ground wire and jumpers:** Insulated conductor connects equipment, racks, cabinets, pedestals and pipes to the rack and grounding busbars.
5. **Rack busbars:** Consolidate equipment grounds on racks and cabinets.
6. **Pedestal clamp with grounding connector:** Connects raised access floor pedestals to the grounding busbar or supports bare ground wires to make a signal reference and grid.
7. **Pipe clamp with grounding connector:** Attaches ground wires to metal pipes.
8. **Cable runway ground strap kit:** Bonds cable runway across splices.

<http://www.cablinginstall.com/articles/2013/12/cpi-key-ground-bond-components.html>



# E. Grounding

- Grounding systems are also used for lightning protection, surge protection, electromagnetic pulse and voltage transient

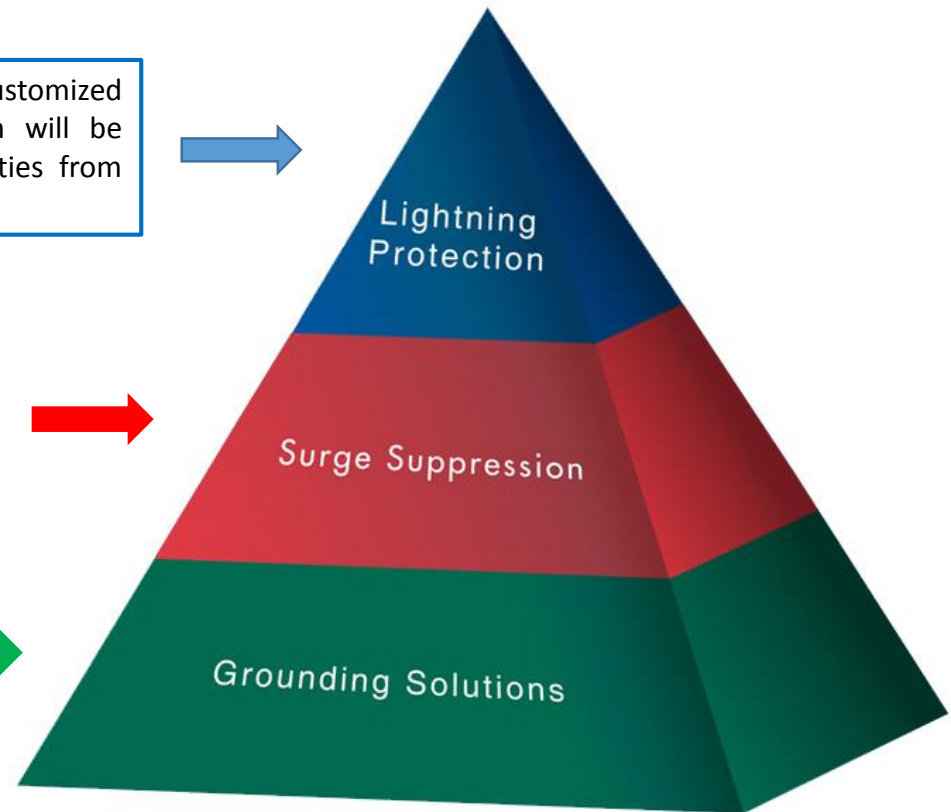
Finally, a well-designed, customized lightning protection system will be installed to safeguard facilities from direct lightning strikes.



the second tier comes from properly installed surge protection devices, which reduce the magnitude of random, high energy, short duration electrical power anomalies



the foundation tier begins with the design of a stable, low resistance and low impedance grounding system that directs harmful electrical currents safely to earth

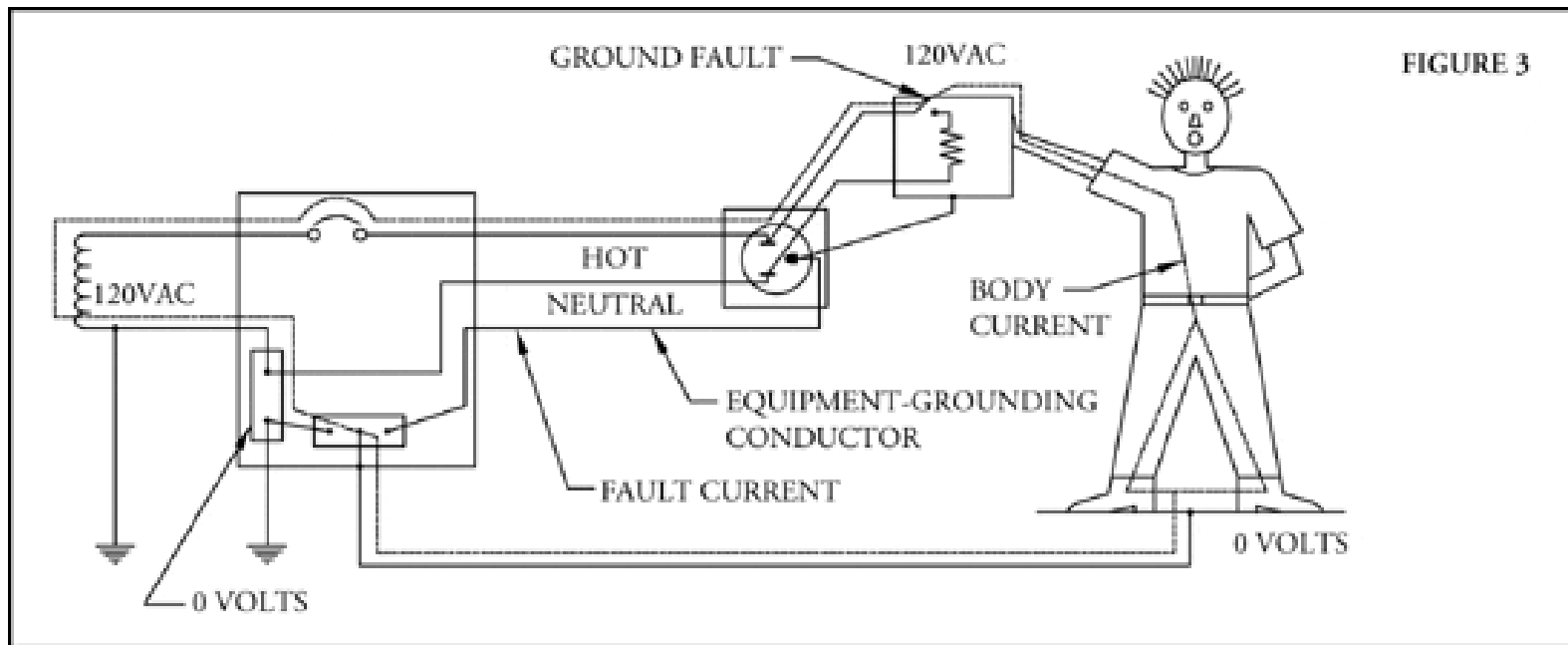


<http://alltecglobal.com/about/alltec-protection-pyramid>



# E. Grounding

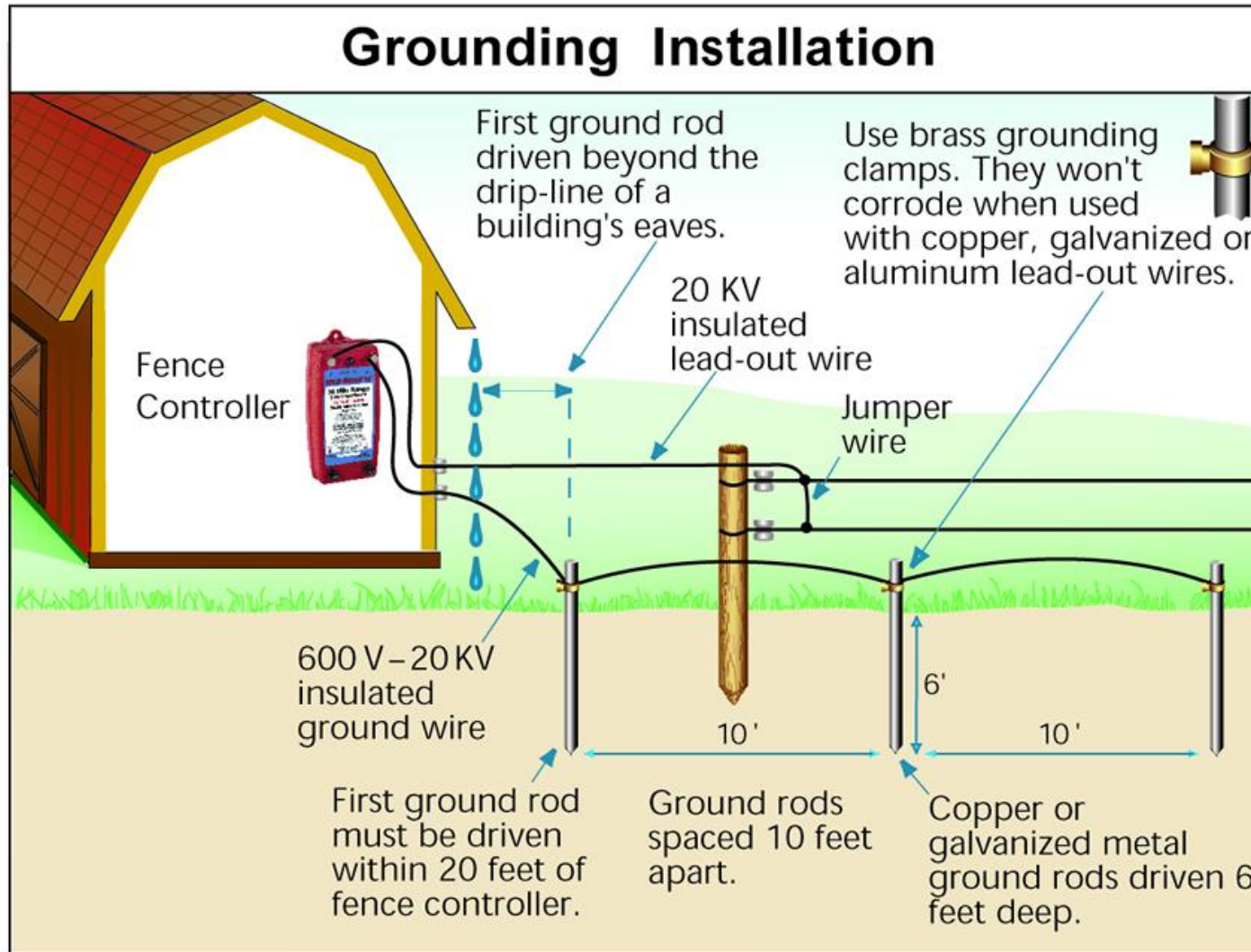
- A good grounding system need to be able to prevent hazardous stray voltage. This in turn reduce the risks of fire and personnel injuries



[www.epgco.com/equipment-grounding.html](http://www.epgco.com/equipment-grounding.html)



# E. Grounding





# E. Grounding

- Ground rod and ground cable must be mechanically bonded with approved connection methods
- Most building codes have minimum ground resistance limits (5 ohms) and specific details such as length of ground rods, mechanical bonding types, cable sizes, etc



# Workmanship Checklist

- A checklist needs to be developed for each local area based on safety codes and local requirements

- This workmanship checklist should cover specific workmanship details related to the installation, operation and maintenance of the system



- A good starting point is to look through local and national requirements and develop the checklist from these documents. Often they already contain compliance checklists



# Workmanship Checklist

- For solar PV installations that may cover several documents, this checklist help the installer perform their work professionally and to meet the requirements



# Sample Workmanship Checklist



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General Checklist		
1	No visible damage to any equipment	
2	Safe access to all necessary equipment for inspection and maintenance	
3	All circuit breakers, fuses, switches and disconnects clearly labeled with their ratings	
4	Schematic diagram of the system is posted clearly on a durable material	
5	Each component clearly labeled (fuses, breakers, switches, wires)	
6	Cable color code complies with local regulations	
7	All metal parts protected adequately against corrosion	
8	All joints at metal conduit are mechanically sound and electrically continuous	
9	Metal conduits are adequately earthed	
10	All exposed metal parts and enclosures are adequately earthed with approved mechanical bonding	
11	Overhead lines are high enough to avoid traffic damage (minimum 4 meters for human traffic only)	
12	Cables adequately protected against mechanical damage (including abrasion on rough surfaces)	
13	DC cabling separated between positive and negative	
14	Grounding system installed according to regulations	
15	Surge protection devices installed properly	
16	DC disconnects and AC disconnects installed properly, labeled clearly and easily accessible	
17	All installed equipment comply to the engineering drawings and documentations	
18	All cables and protection devices have been calculated to withstand the electrical current	
19	All cables are protected from damage	
20	Warning notices and labels installed properly and made of durable materials	
21	All bolts and screws are torqued to specification (including on breakers and fuse holders)	
22	All mechanical mounting devices are secure and level	
23	Solar PV mounting system was installed to manufacturer's specification and safety codes	



# Sample Workmanship Checklist



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Example Detailed Checklist (according to local safety and building codes)		
1	Grounding electrode resistance measurement of less than 25 ohms (as tested per regulation)	
2	Overhead wires installed at more than 5.2 meters (foot traffic) or 5.8 meters (vehicle traffic)	
3	Solar PV panels are not shaded at any time of the day and in the foreseeable future	
4	Rooftop mounting system did not damage the roof integrity	
5	Unprotected outdoor cables are UV resistant and rated for outdoor use without protection	
6	Solar PV panels are at least 100mm from the roof surface	
7	MCB terminal screws are tightened to 1.7Nm (or as specified by the manufacturer)	

- The detailed checklist uses the specific requirements and limitations from the relevant regulations.
- This checklist need to be built by each company who does the solar PV installation work.
- Once the general checklist and the detailed checklist for the workmanship is finished, it can be used by the technician as a guideline that they've done the work according to a high standard.
- Ideally the checklist reflects the standard operating procedure of the company, and hopefully the market in general





# Asia-Pacific Economic Cooperation

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