Solar PV for Fire
&
Code Officials

Summer, 2016

Trainer: Dan Lepinski, P.E.

Sponsored by:

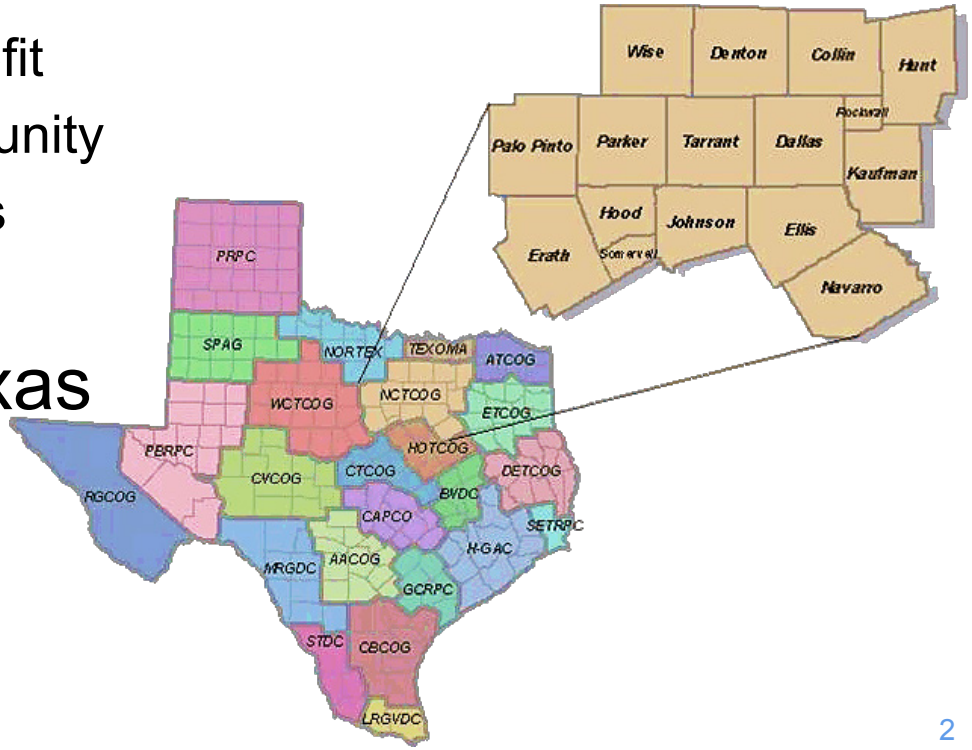
North Central Texas Council of Governments

SECO
State Energy Conservation Office

www.GoSolarTexas.org

What is NCTCOG?

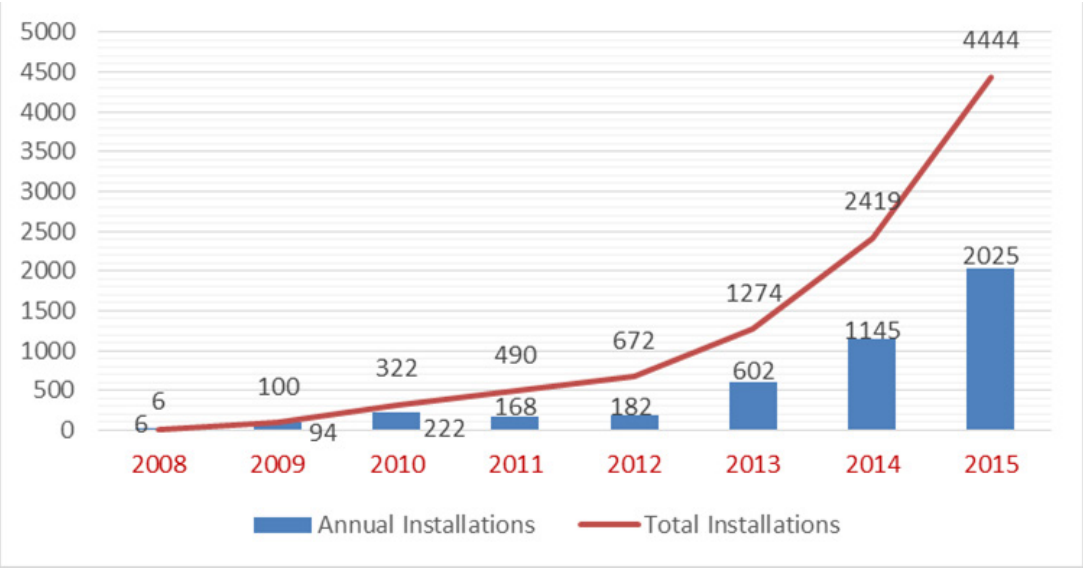
- Voluntary association of local governments
- Established in 1966
- Assists local governments in:
  - Planning for common needs
  - Cooperating for mutual benefit
  - Recognizing regional opportunity
  - Resolving regional programs
  - Making joint decisions
- One of 24 COGs in Texas
- www.nctcog.org



NCTCOG's SOLAR PROGRAM GOALS

1) Provide resources for cities
2) Improve air quality by reducing demand for electricity during peak loads
3) Increase local energy and grid reliability
4) Reduce costs

Dallas-Fort Worth Region Annual Installations and Total Installations (2008 to 2015)



REGIONAL STATISTICS:

- **744% growth in # installations since 2008**
- **4,469 total installations in 123 cities**
- **43,626 kW = Approximate regional installed solar capacity** (Source: NTREG, 2016)
- **2.1 tons NOx avoided annually**

Solar Energy for Fire & Code Officials

Dan Lepinski, P.E.

Solar Energy for Local Governments

Presented in Collaboration with…

Texas State Energy Conservation Office

&

North Central Texas Council of Governments

Celebrating 50 Years Serving Citizens in North Texas and Throughout the State of Texas.

SECO State Energy Conservation Office

North Central Texas Council of Governments

GO SOLAR

Disclaimer

This Workshop is prepared in cooperation with the North Central Texas Council of Governments (NCTCOG), the State of Texas Energy Conservation Office (SECO), and the U.S. Department of Energy (DOE).

The contents of this presentation reflect the view of the author, who is responsible for the opinions, findings, and conclusions presented herein.

The contents do not necessarily reflect the views or policies of the North Central Texas Council of Governments, the Comptroller of Public Account's State Energy Conservation Office, and the U.S. Department of Energy (DOE).

Solar Energy for Fire & Code Officials

- Brief History & Overview of Solar Energy with Definitions
- Components of a Solar Energy System
- Types of Solar Energy Systems
- Misconceptions About Solar Energy Systems
- Safety Labeling for Firefighters
- Firefighter Concerns
- Inspecting Systems for Code Compliance
- Changes Coming in the 2017 National Electric Code
- Q &A

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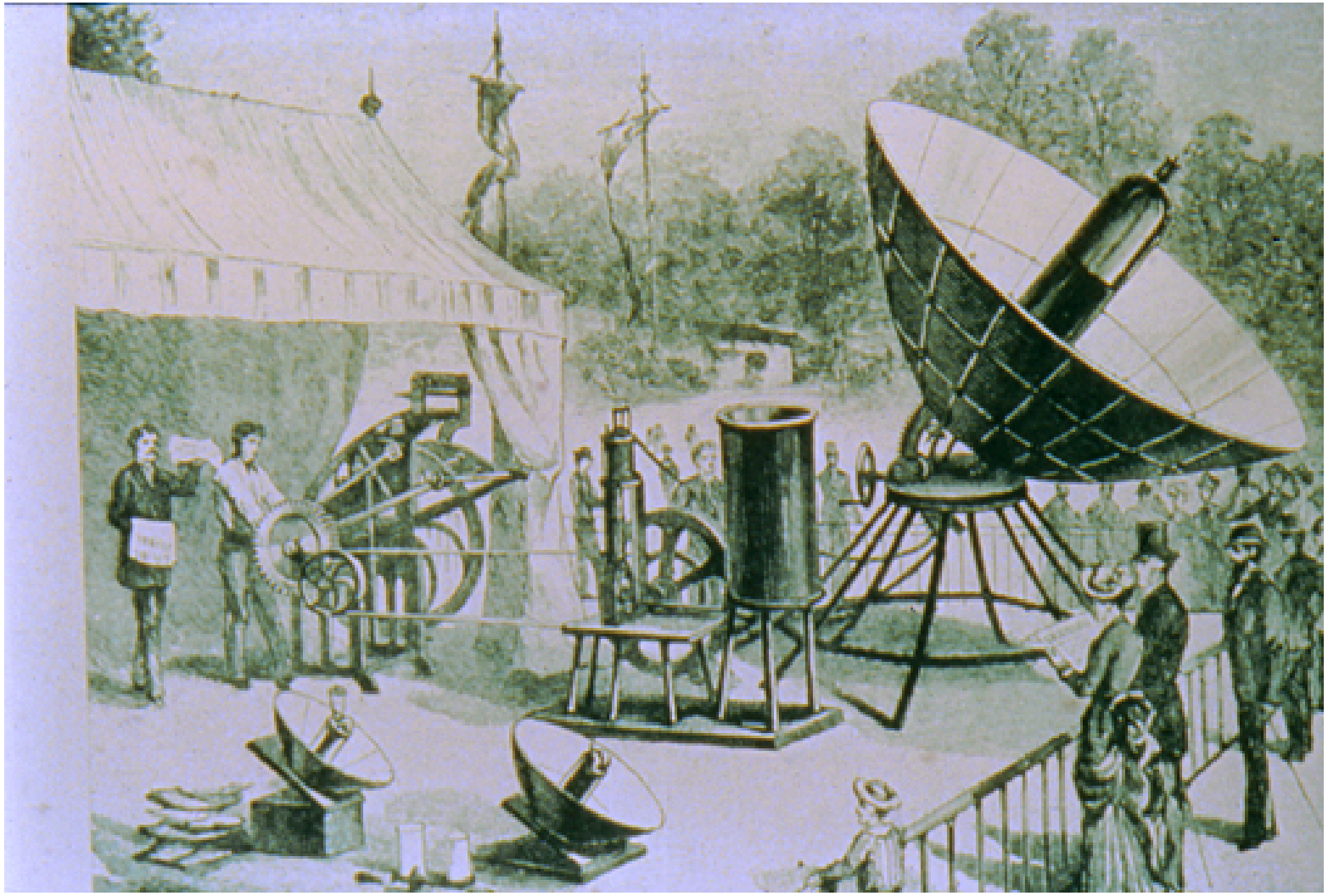
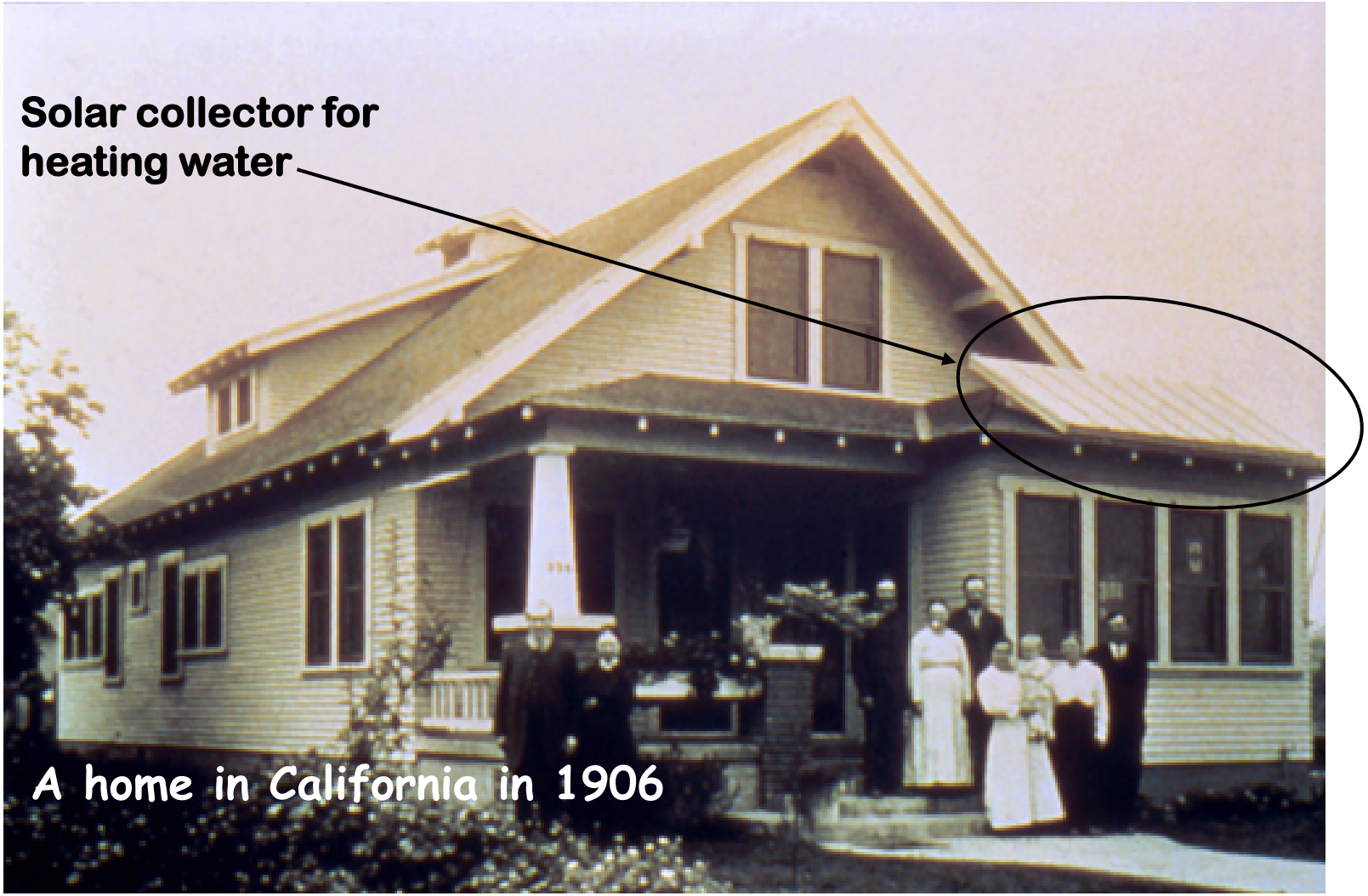
Solar Energy Isn't New…

This illustration is from the 1890's World Fair.



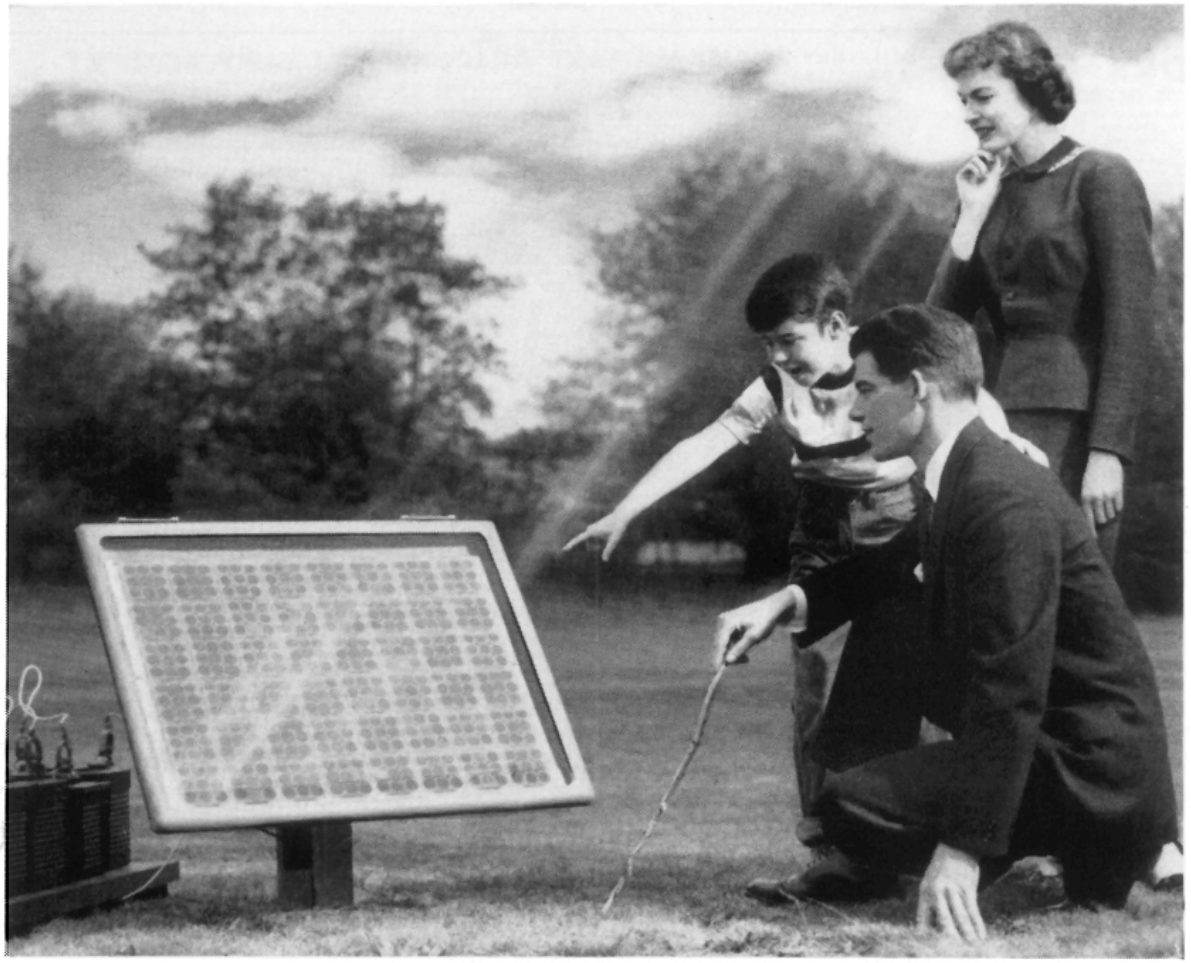
Solar Energy Isn't New…

This example is from California in 1906.



Solar Energy Isn't New…

1955 Bell Telephone Ad Promoting Solar Electricity. Bell Labs is credited with inventing solar cells.



Something New Under the Sun. It's the Bell Solar Battery, made of thin discs of specially treated silicon, an ingredient of common sand. It converts the sun's rays directly into usable amounts of electricity. Simple and trouble-free. (The storage batteries beside the solar battery store up its electricity for night use.)

Introduction to Terminology

Electricity, Power, and Energy

Photovoltaic ("PV"): Electricity from light.

Solar Cell: Converts sunlight into electricity.

Photovoltaic Module: Multiple solar cells connected in one unit.

Photovoltaic Array: Multiple photovoltaic modules.

Direct Current ("DC"): Electricity that flows in one direction.

Alternating Current ("AC"): Electricity that changes direction.

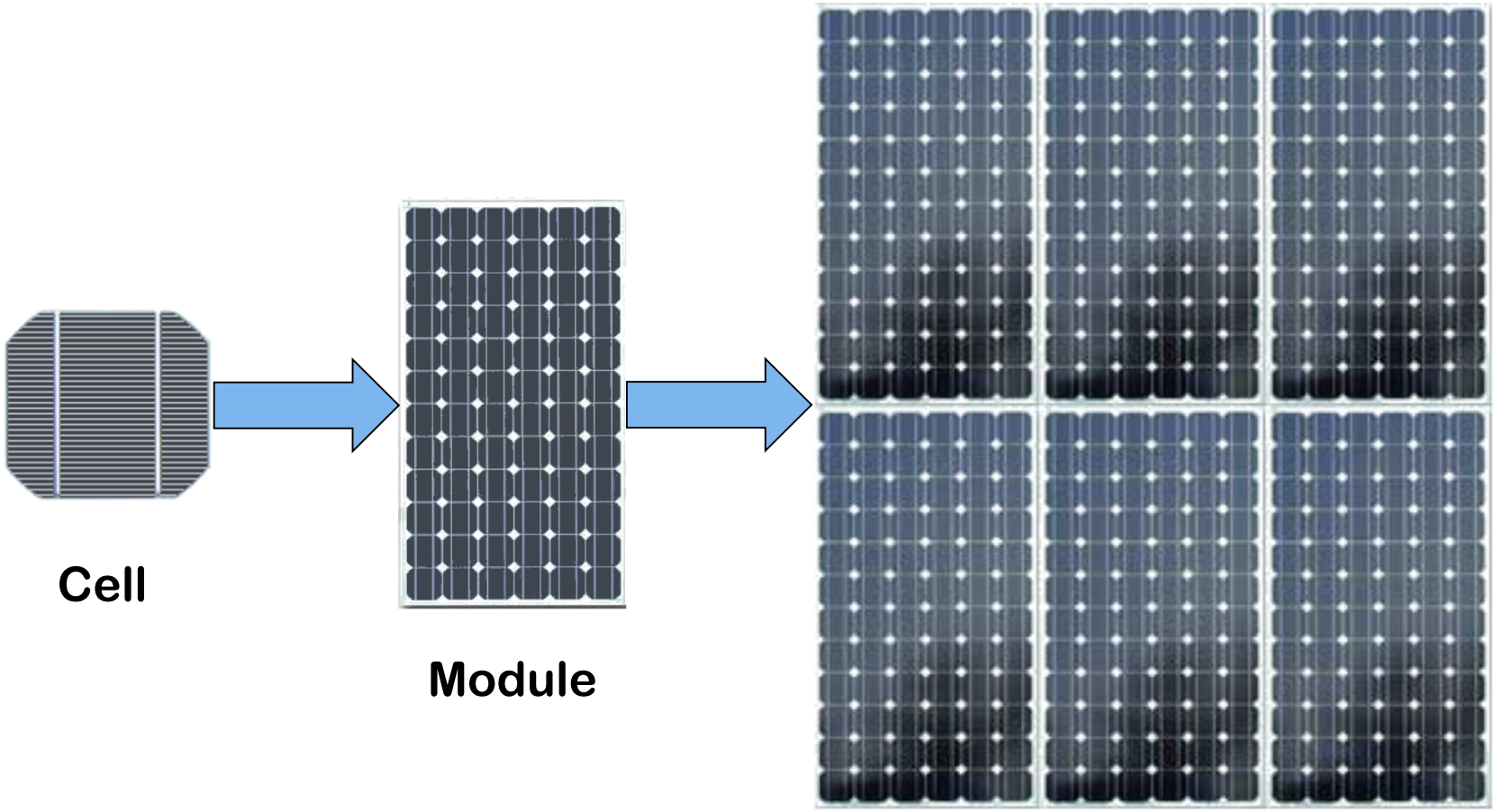
Watts: Electrical power at any given moment.

Watt-hours: Quantity of electrical power over time.

Kilo: 1,000 of something.
1,000 watts = 1 kilowatt
1,000 watt-hours = 1 kilowatt-hour

Inverter: Device that changes DC to AC.

Definitions: Solar Cell, “PV” Module, Array



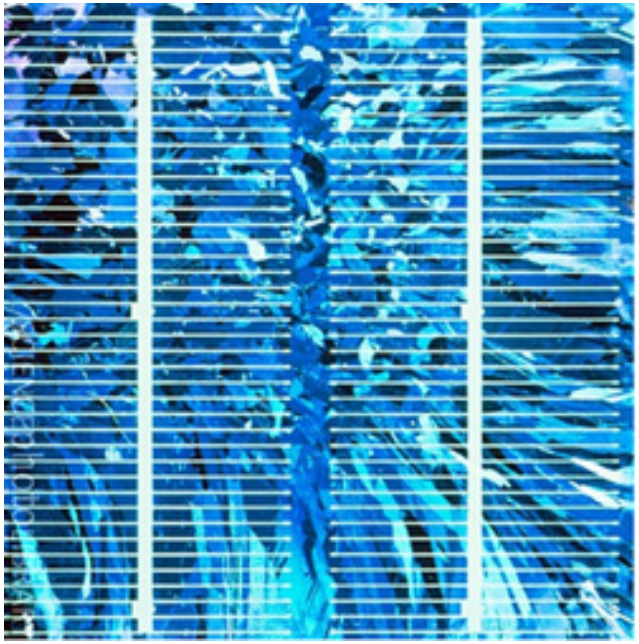
Cell

Module

Array

Most solar cells are dark blue to black…

Monocrystalline Cell



Polycrystalline Cell

Both are silicon. Manufacturing methods differ.

Some solar materials are reddish-brown or gray…

Amorphous Silicon

Cadmium Telluride

Copper Indium
Gallium Selenide

Basic Overview - Solar Electricity Works Like This…

Photovoltaic modules convert sunlight into electricity.

"Inverter" - changes solar "DC" into household "AC".

Utility meter: Measures power consumed and all excess power fed back to the utility grid.

The solar electricity serves the building loads **first**. Any excess is fed out to the utility grid to the neighbors, and may accrue credit to the owner.

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Basic Overview - Components - PV Modules

Basic Overview - Components - "BIPV"

May be integrated into the roof. Not as common as individual modules.

Basic Overview - Components - PV Modules

PV Module Construction

Tempered Glass

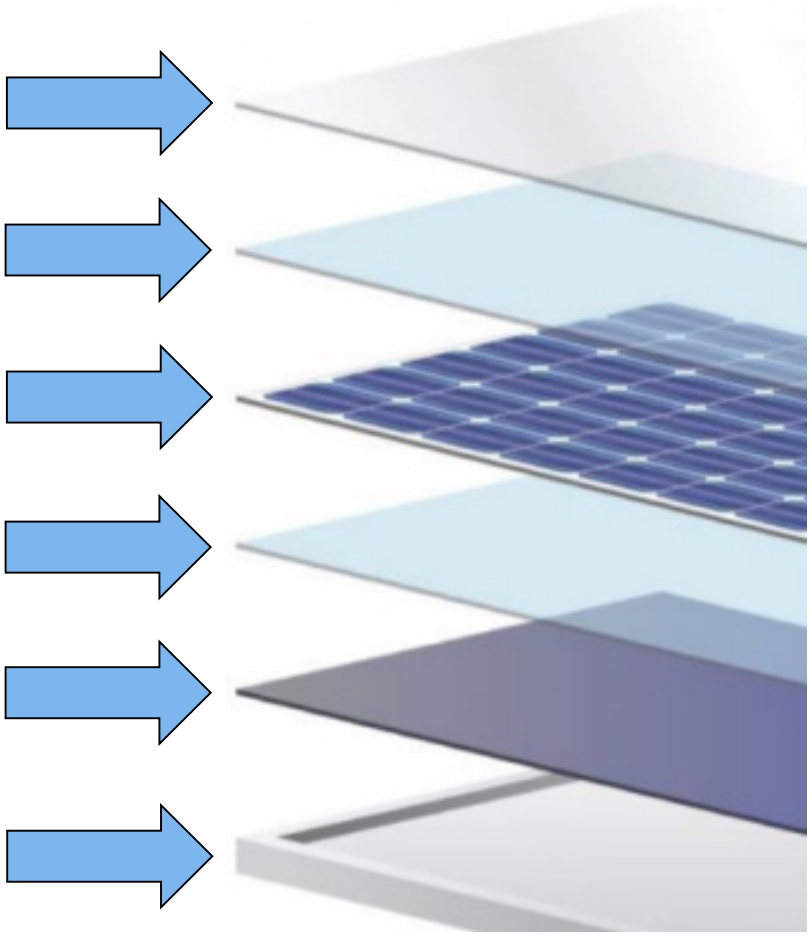
Ethelene Vinyl Acetate ("EVA")

Solar cells

Ethelene Vinyl Acetate ("EVA")

Backsheet

Aluminum Frame



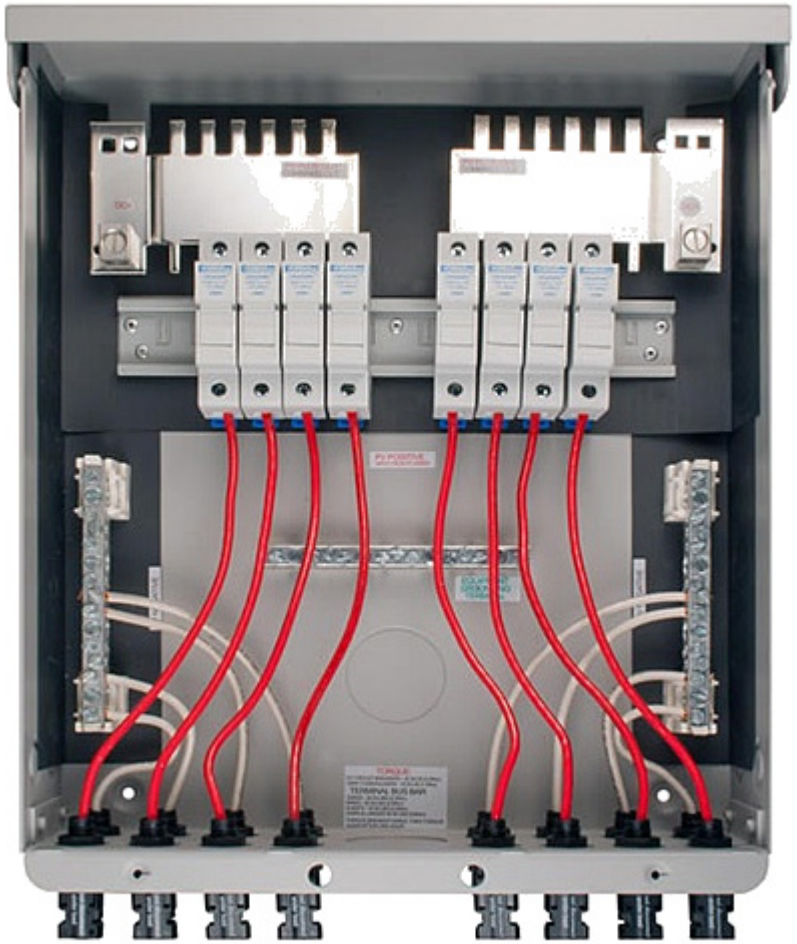
Must withstand a minimum 1" hailstone at 55 mph. (UL 1703)

Survive 25+ years of heating and cooling.

Seals environment out for 25+ years.

Supports snow, and withstands wind.

Basic Overview - Components - DC Combiner Box



- Mounts near the PV array. 2 to 20 circuits in -- one circuit out.
- DC combiners for three or more circuits MUST be fused.
- Same DC voltage as one string - current is multiples of numbers of strings

Image Credit: Midnite Solar

Basic Overview - Components - AC Combiner Box

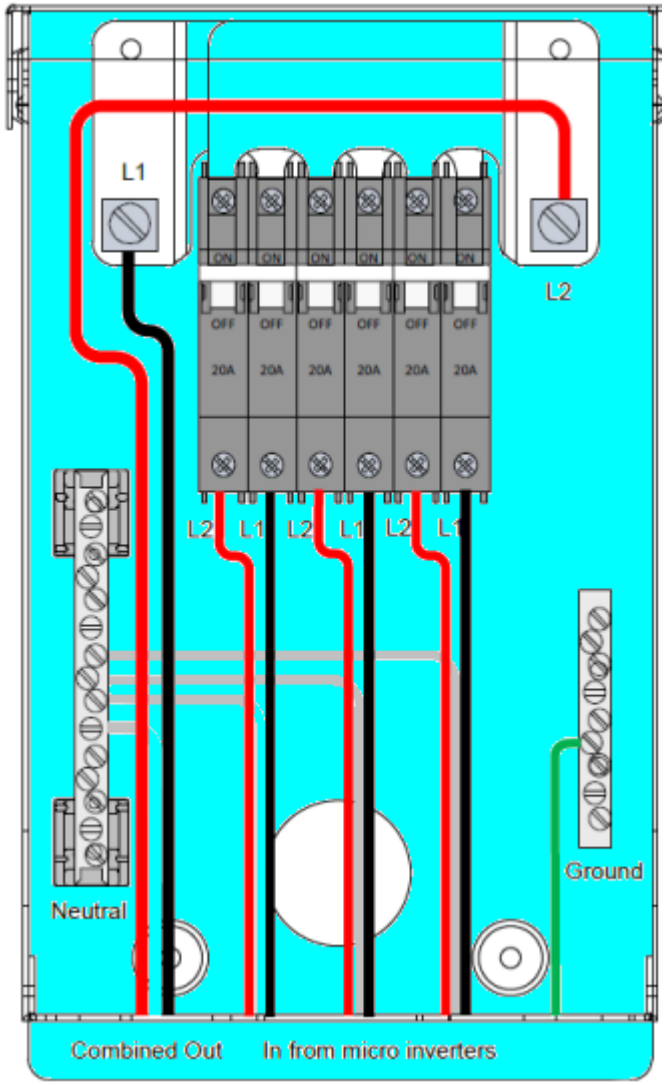


Image Source: Enphase Energy

Basic Overview - Components - DC Disconnect

Example only. Other Listed brands and models are also suitable.

- Must be rated for DC operation at the highest allowable DC voltage.
- Over-current protection may be required. Must also be DC-rated.

Source: Enphase Energy

Basic Overview - Components - Microinverter

- Mount behind PV Module in ALL cases.

Photo Credit: Enphase Energy (left), EnecSys (center), Solarbridge (right)

Basic Overview - Components - String Inverter

- May mount to a wall, racking, or other vertical location.
- UL 1741 requires mounting above sprinklers or other water sources.
- Some units have integral DC and/or AC disconnects.

Photo Credit: Refusol (left), SMA America (right)

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Basic Overview - Components - String Inverter

Multiple inverters may be connected to a point of common connection.

Photo Credit: SMA America

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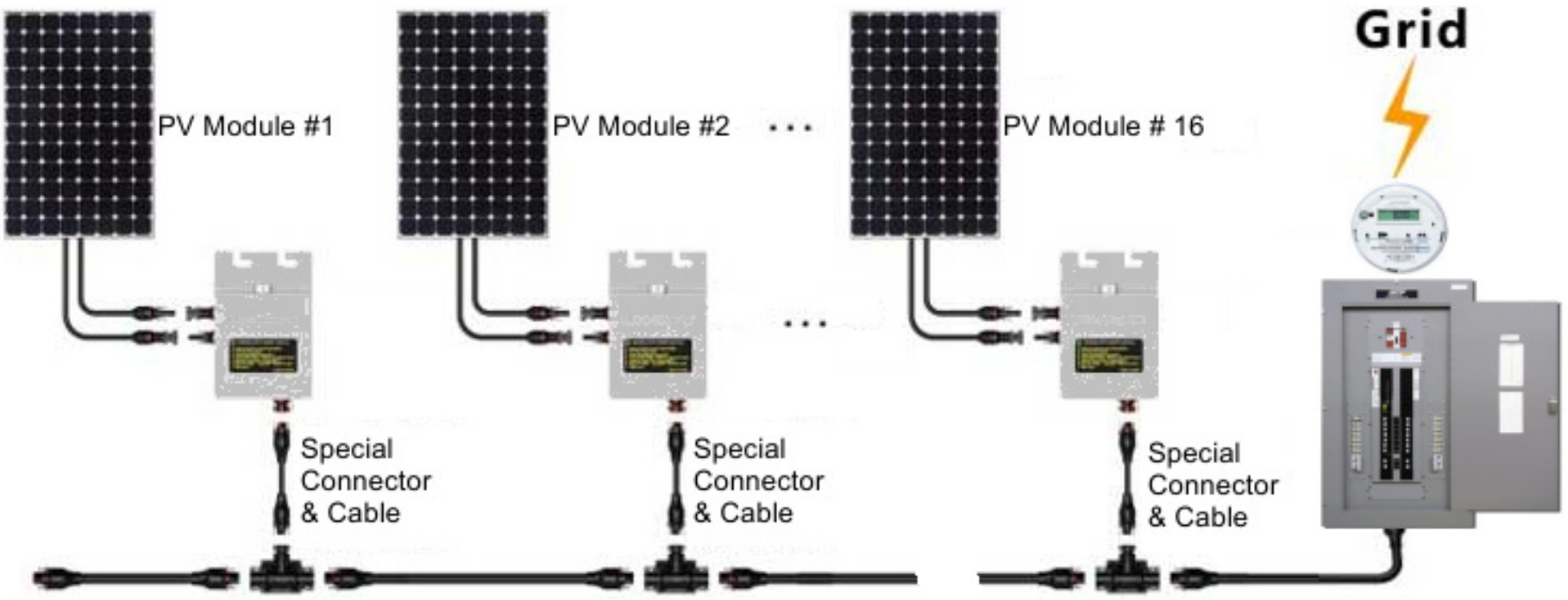
Basic Overview - "Microinverter" System



Microinverters

Some Considerations for Firefighters and Code Officials:

1. No high-voltage DC present anywhere in the system.
2. "Rapid Disconnect" not required per the NEC.
3. All exposed conductors are AC only, same as any branch circuit.
4. If the meter is pulled, this system will cease operating immediately.

Image Credit: Enphase Energy

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Basic Overview - "Microinverter" System

Microinverters:
Typically 200-350 Watts each.

Attach to racking or PV modules.

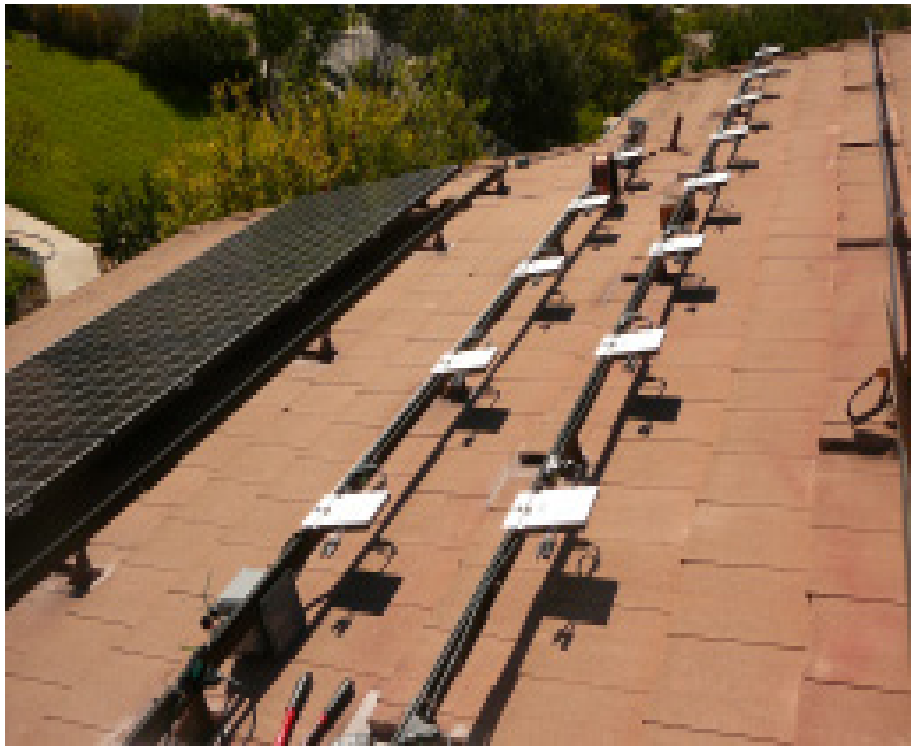
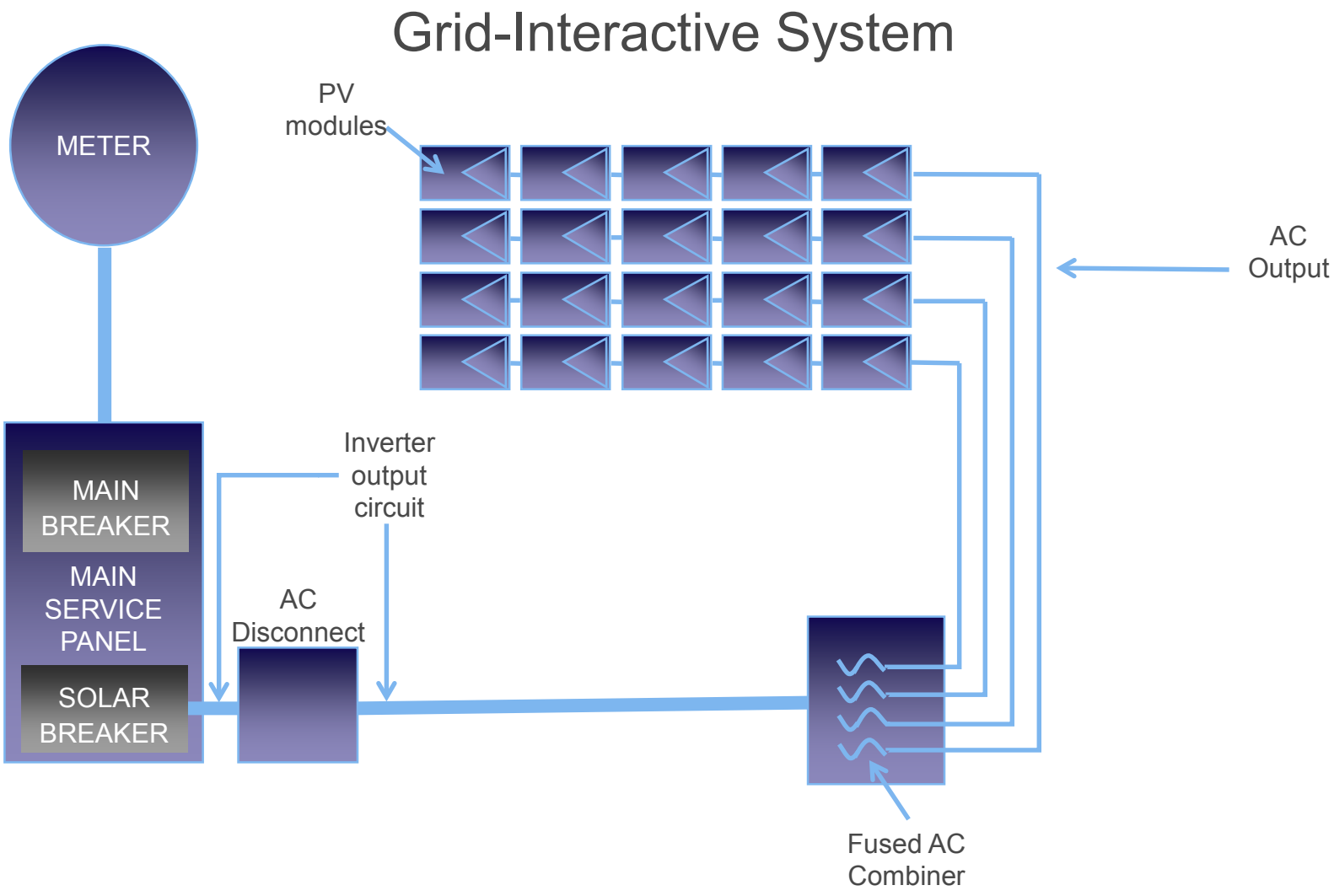


Photo Credit: Solar Pro Magazine

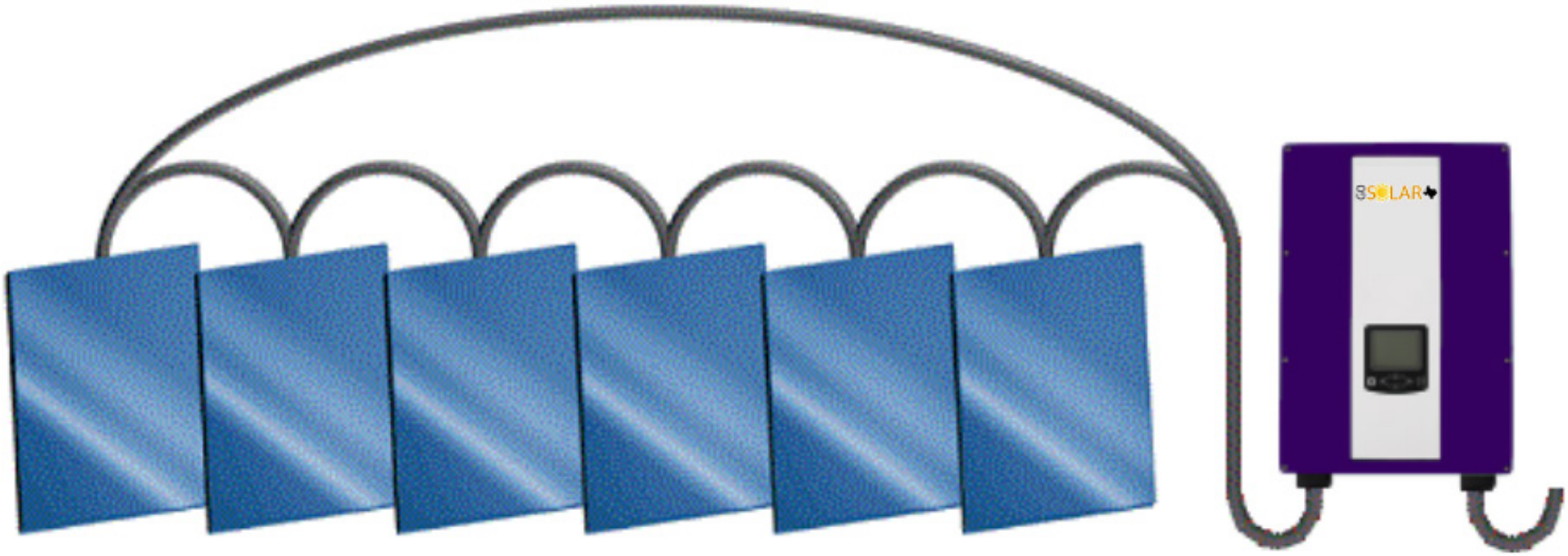
Basic Overview - "Microinverter" System Diagram

Grid-Interactive System Block Diagram



Basic Overview - "String" Inverter System

Solar panels are connected one to another .. in a "string".



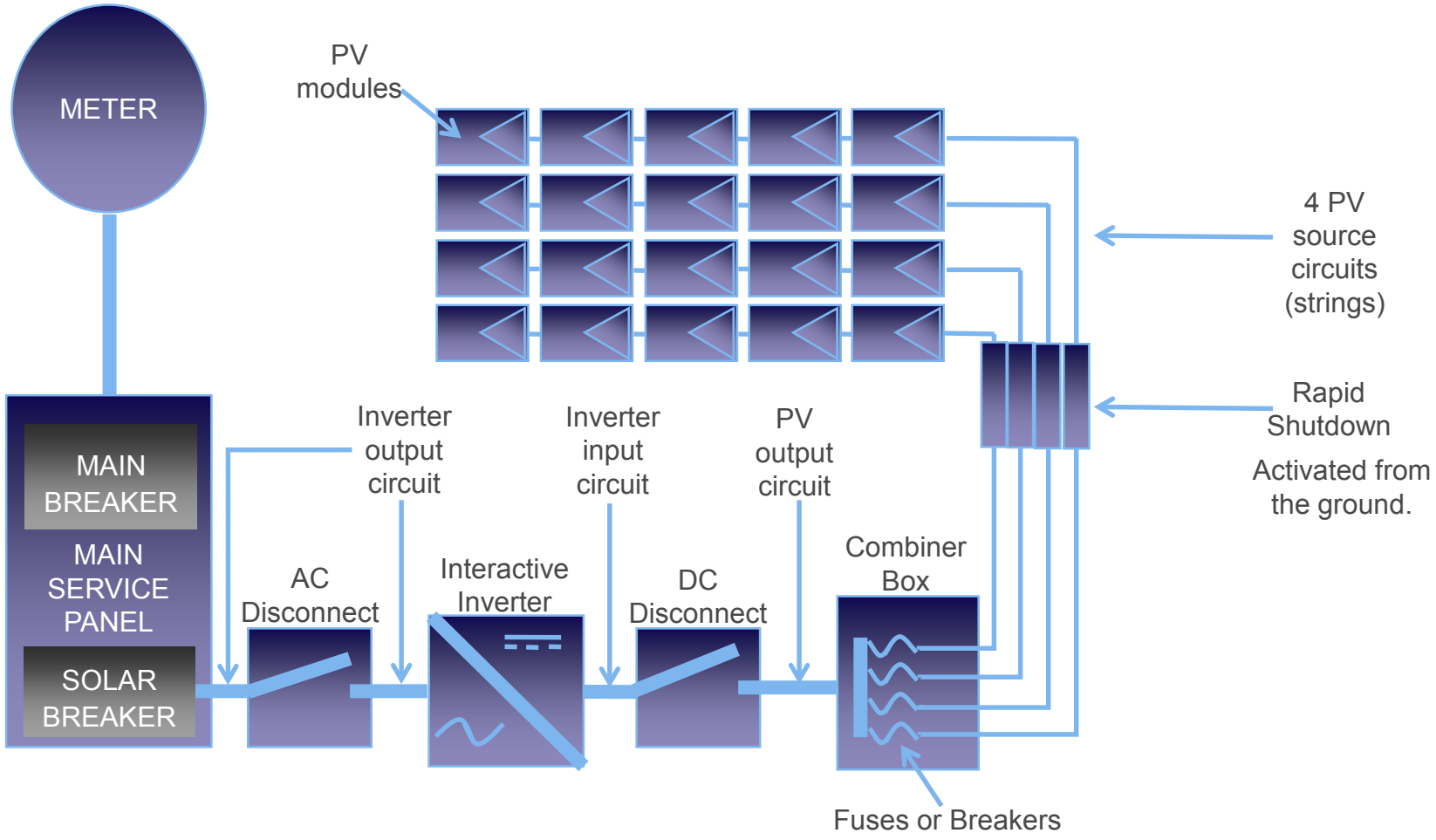
Some Considerations for Firefighters and Code Officials:

1. May have up to 1,000 volts DC present in some installations.
2. Local code may require "Rapid Shutdown" hardware.
3. When illuminated, PV generate voltage, even if the system is "OFF".
4. If the meter is pulled, this system will cease operating immediately, but PV will have voltage present if illuminated.

Note: Some required hardware omitted for simplicity.

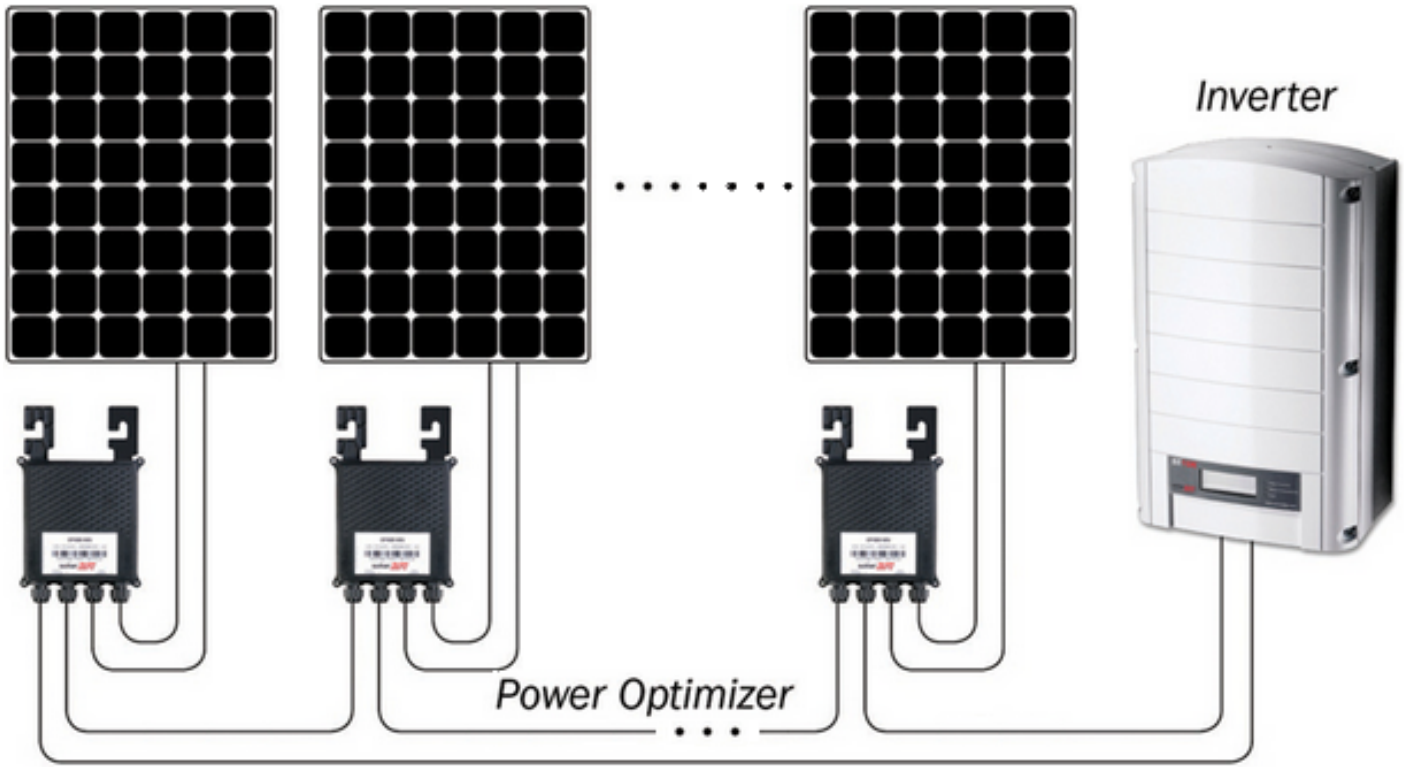
Basic Overview - "String" Inverter System

Grid-Interactive System Block Diagram



Basic Overview - "String" Inverter System

Grid-Interactive “Power-optimizer” String System



“Optimizers” resemble microinverters, but aren’t. They’re part of a “string” inverter system. The system operates at high voltage like an ordinary system, but stop producing DC voltage if the inverter stops.

Optimizer-based systems do not require “Rapid Shutdown” hardware.

Image Credit: Solar Edge

Basic Overview – Examples of PV Mounting Methods

Residential Systems

Photo Credit: Solar Pro Magazine

Basic Overview – Examples of PV Mounting Methods

Commercial Systems

Photo Credit: Solar Pro Magazine

Basic Overview – Examples of Racking

Racking Before PV Are Attached – Horizontal Mount

Horizontal rails offer lateral placement latitude.

Photo Credit: Solar Pro Magazine

Basic Overview – Examples of Racking

Racking Before PV Are Attached – Vertical Mount

Vertical rails offer placement latitude vertically.

Photo Credit: Solar Pro Magazine

Basic Overview – Examples of Mounts and Standoffs

'L' Feet

Elevated Flashing.
Often required by building codes.

Basic Overview – Examples of Commercial Racking

Ballast Mounts

Commercial "ballasted" mount. This model uses plastic trays.

Another ballasted array. This one uses aluminum plates for the ballast blocks.

Photo Credit: Iron Ridge www.ironridge.com

Basic Overview – Examples of Commercial Racking

Ballast Mounts

Ballasted mounts allow flexibility in placement with minimal or no roof penetrations.

Basic Overview – Examples of Systems

Building-Integrated Photovoltaic Systems ("BIPV")

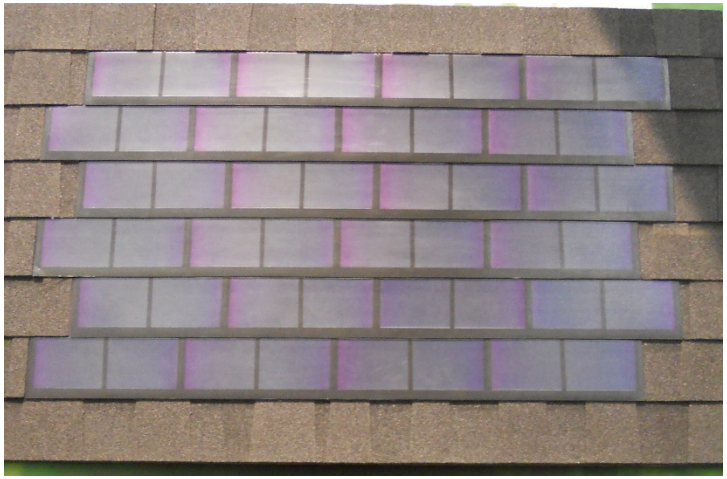


Photo Credit: Solar Pro Magazine

Basic Overview – Examples of PV Mounting Methods

Ground-Mount Systems

Photo Credit: Solar Pro Magazine

Basic Overview – Examples of Systems

Systems With Battery-backup

The presence of batteries in a system isn't common, but is increasing.

Batteries may not always be visible, as shown above..

Photo Credit: Solar Pro Magazine

Basic Overview - "String" Inverter System

Grid-Interactive System Example

Actual System: (1) Inverter, (2) DC disconnect, (3) solar production meter, (4) AC disconnect, (5) utility meter. (Battery-less.)

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QUESTIONS?

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Solar Energy for Fire & Code Officials

Misconceptions About Solar Energy Systems

Pulling the utility meter will render a photovoltaic system inoperative.

FALSE.

Removing the utility meter will stop AC power generation from the inverter(s), but does NOT stop the PV modules from generating DC voltage if they're illuminated.

In typical "string" systems, up to 600 volts DC may be present. Newest systems may have up to 1,000 volts DC, and 1,500 volt systems are on the horizon.

Solar Energy for Fire & Code Officials

Misconceptions About Solar Energy Systems

Activating the "Rapid Shutdown" system turns off the DC voltage.

FALSE.

The "Rapid Shutdown" system disconnects the DC voltage from the remainder of the circuit. The PV is still very much active on the "other" side of the rapid shutdown circuit. All rapid shutdown does is move the disconnect point closer to the PV array.

In addition, if the system has a "battery backup", and the utility meter is removed, the battery backup feature may activate, disconnect the system from the utility lines, and continue to provide AC power to select circuits inside the structure.

Solar Energy for Fire & Code Officials

Misconceptions About Solar Energy Systems

PV are safe at night because it's dark.

"IT DEPENDS..."

If it's totally dark, yes. Even bright moonlight isn't sufficient to cause measurable power output.

However...

In the event of a fire, scene lighting may produce enough illumination to generate several hundred volts, and could result in a lock-on condition if contacted.

This has been verified by Underwriters Laboratories.

Photo Credit: Underwriters Laboratories

Solar Energy for Fire & Code Officials

Misconceptions About Solar Energy Systems

Flat panels on the roof indicate the presence of solar panels.

FALSE.

Not all "flat panels" are solar electric. They may be solar hot water, or solar hot air.

Most solar hot water panels resemble solar electric panels, but have obvious plumbing attached.

Other solar hot water collectors resemble large test tubes (4' long each), and are not electric .. but MAY contain hot water >150° F.

Solar Energy for Fire & Code Officials

Misconceptions About Solar Energy Systems

Flat panels on the roof indicate the presence of solar panels.

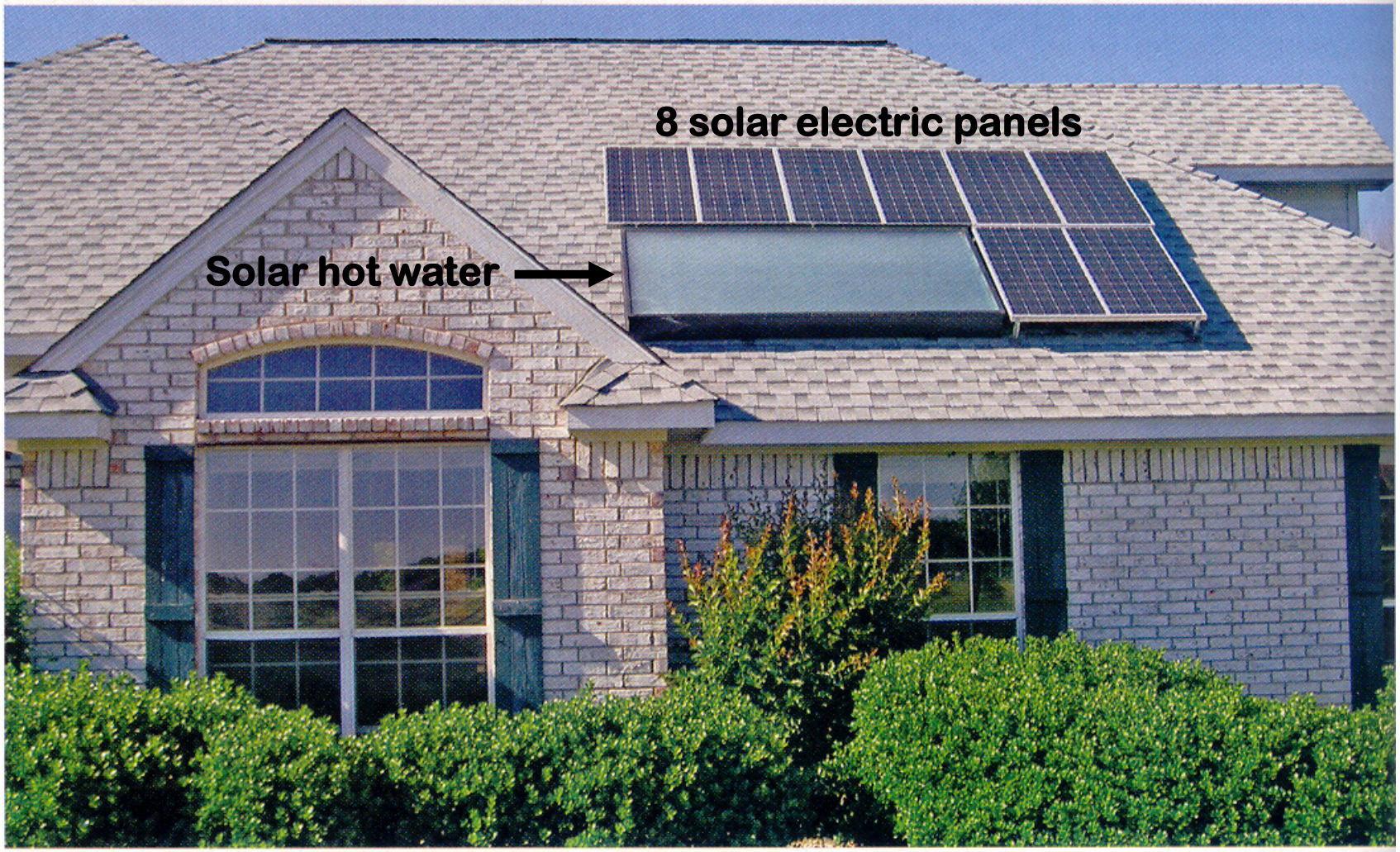

Photo Credit: DL

Solar Energy for Fire & Code Officials

Misconceptions About Solar Energy Systems

A "hot stick" will detect the presence of DC voltage.

FALSE.

A hot stick will only detect the presence of AC voltage, regardless of its sensitivity.

Solar Energy for Fire & Code Officials

Misconceptions About Solar Energy Systems

Solar panels will be obvious if present.

FALSE.

Dow Corning and others manufacture "solar shingles" that resemble ordinary composite shingles.

Under some conditions, they're almost impossible to see.

Photo Credit: National Renewable Energy Laboratory.

Solar Energy for Fire & Code Officials

Misconceptions About Solar Energy Systems

"Tarping" will block sunlight from the solar panels and render them safe.

FALSE.

Tarping is only effective if done with heavy, opaque canvas tarp or very dark to black plastic film. These have been tested by Underwriters Laboratories. Care should be exercised when tarping, as a wet tarp may conduct electricity. Gloves and boots should not be considered adequate electrical PPE.

Tarping should be done after a fire is out to prevent voltage from being generated while the scene is worked afterwards. Tarps should be left in place as long as danger of short circuits or arcing may exist.

ALSO! Be aware of conditions! Wires damaged during a night-time fire may become energized when the sun comes up and illuminates the solar panels the next morning. Damaged or melted insulation could cause electrical conduit to become "live" as well.

Solar Energy for Fire & Code Officials

Misconceptions About Solar Energy Systems

Solar panels are heavy.

FALSE.

The aluminum frame makes them LOOK heavy, but a PV array - including the mounting rack - adds approximately 2.5 pounds per square foot to the roof.

Frames are thick to allow the PV to withstand snow loads, and to survive high winds when mounted separately.

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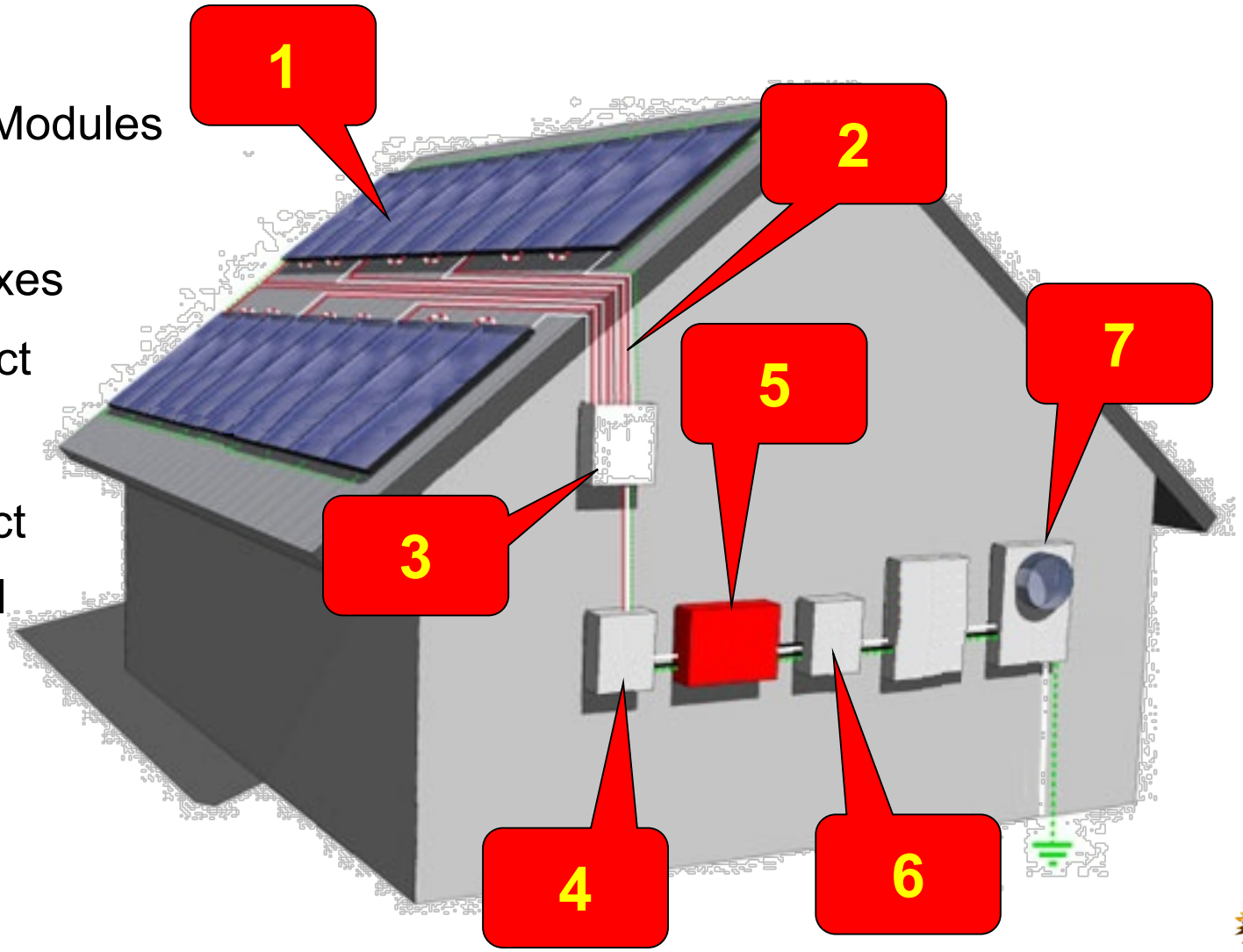
Solar Energy for Fire & Code Officials

Safety Labeling for Firefighters

1. Photovoltaic Modules
2. DC Conduit
3. Combiner Boxes
4. DC Disconnect
5. Inverter
6. AC Disconnect
7. Service Panel



Solar Energy for Fire & Code Officials

Safety Labeling for Firefighters

1. DC Conduit, cable trays, raceways (not all-inclusive):
2. DC Combiner Boxes (not all-inclusive):

Solar Energy for Fire & Code Officials

Safety Labeling for Firefighters

Conduit Example

Photo Credit: Solar Pro Magazine

Solar Energy for Fire & Code Officials

Safety Labeling for Firefighters

3. Hidden Circuits

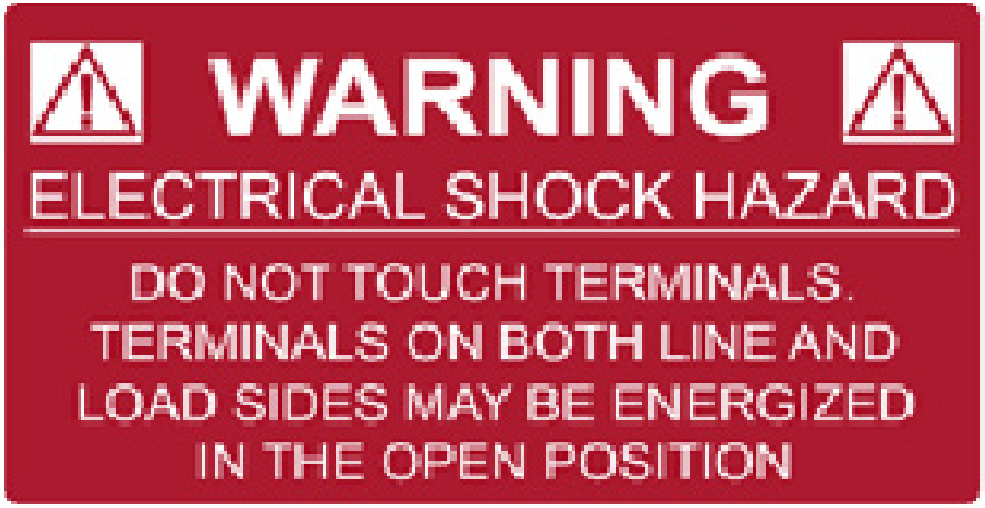
Per NEC690.4(F), installer must clearly mark hidden circuits.

Photo Credit: Hellermann Tyton Corp

Solar Energy for Fire & Code Officials

Safety Labeling for Firefighters

4. DC & AC Breakers and Disconnects (not all-inclusive):



Solar Energy for Fire & Code Officials

Safety Labeling for Firefighters – Actual Example of Label #4.

Photo Credit: Solar Pro Magazine

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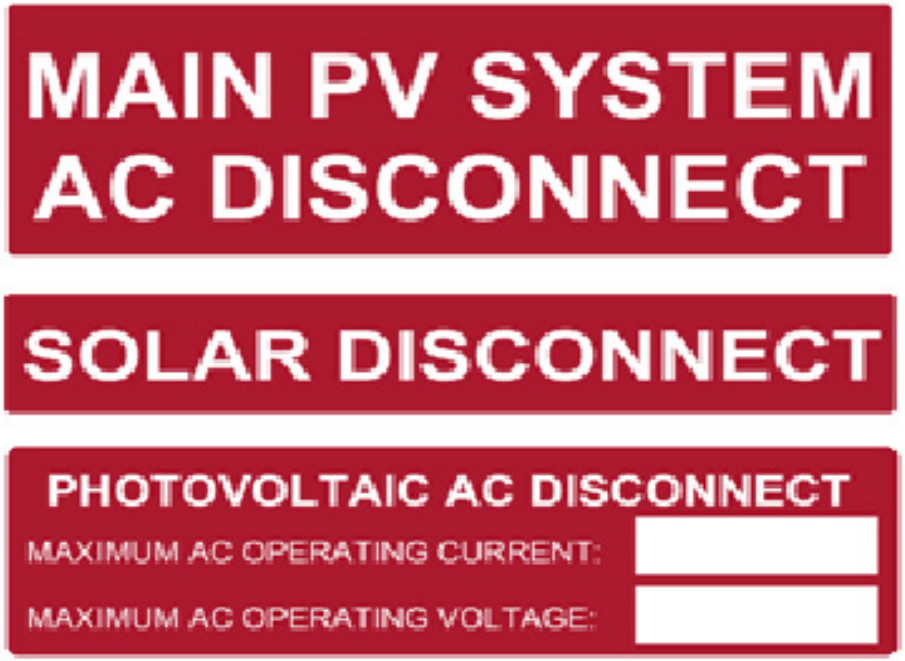
Solar Energy for Fire & Code Officials

Safety Labeling for Firefighters

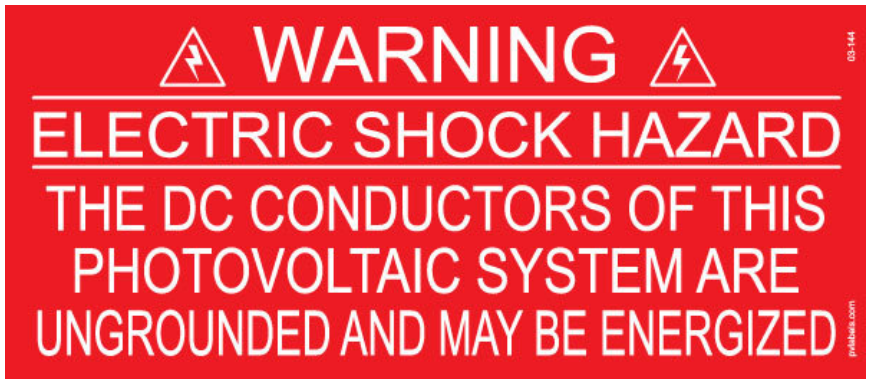
4. DC & AC Breakers and Disconnects (not all-inclusive):



Solar Energy for Fire & Code Officials

Safety Labeling for Firefighters

5. Inverters (not all-inclusive):



Ground fault: a path for electrical current between any PV cells in a module and the module frame.

Inverters are required by UL Safety Standards to sense ground faults, cease operating if a ground fault is detected, and provide visual indication of the fault.

Solar Energy for Fire & Code Officials

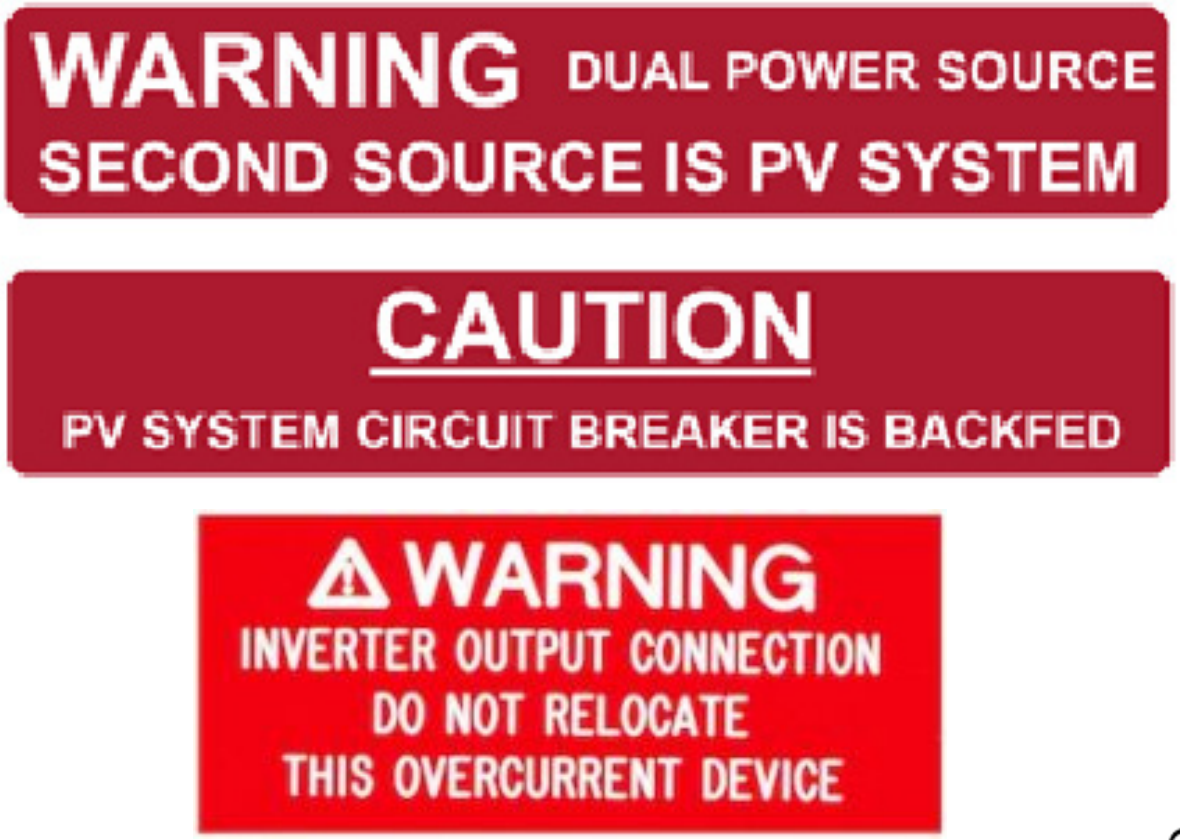
Safety Labeling for Firefighters

6. AC Disconnect

Solar Energy for Fire & Code Officials

Safety Labeling for Firefighters

7. Service Entry and Main Panelboard (not all-inclusive):



8.6 Labeling Requirements: 705.12(D)(2)(3)(b)

- 120% Rule

- When buss bar ampacity is less than main breaker rating + 125% of the inverter current, **solar breaker must be on the opposite end of the buss bar from the main breaker, with this label:**

8.6 Labeling Requirements: 705.12(D)(2)(3)(c)

- New way to calculate breakers on backfed busbar in 2014 NEC, which gives up more options than before.
- Busbar is now protected by the load side breakers.

WARNING:
THIS EQUIPMENT FED BY MULTIPLE SOURCES. TOTAL RATING OF ALL OVERCURRENT DEVICES, EXCLUDING MAIN SUPPLY OVERCURRENT DEVICE, SHALL NOT EXCEED AMPACITY OF BUSBAR

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Firefighter Concerns – FAQ from Firefighters

Q: What toxins may be emitted when PV burns?

A: Fumes from ethylene vinyl acetate, Kevlar®, Tedlar®, polyethylene, rubber, the polymer junction box, and – if hot enough - heavy metals such as cadmium, tellurium, copper, indium, selenium, gallium, arsenic, lead, silver, zinc, and aluminum. Effects are: Cadmium Telluride - a known carcinogen. Gallium Arsenide - highly toxic and carcinogenic. Phosphorus - highly toxic.

Q: What other hazards exist to firefighters when a house is equipped with solar panels – and we respond to a fire there?

A: Shock, slip, trip, broken glass, hindered access for ventilating, sharp edges from aluminum frames, “chimney effect”, and the added weight on the roof.

Q: What happens if the PV glass gets broken (or is already broken) during a fire or fire mitigation efforts?

A: If during the daytime, or the PV are illuminated, there is increased risk of electric shock if contact is made, or through water conductivity.

Solar Energy for Fire & Code Officials

Firefighter Concerns – FAQ from Firefighters

Q: Is there a way to know if there's a battery backup without entering the structure?

A: Generally not. A warning label or sign would need to be placed by the installing company in a highly visible location denoting the presence of batteries. Lacking such indication … no.

Comment: Battery banks pose a shock hazard (i.e. Tesla "Power Wall"), a chemical hazard from sulfuric acid, sulfur, lead, risk of hydrogen explosion, and more.

Q: Can solar panels support the weight of a firefighter?

A: Plastic "Solar shingles" .. Yes. Glass PV Modules? No. The glass will break.

Comment: Do not step on or cut into PV panels during roof ventilation, especially during daylight. Find another place to ventilate if possible, or change your attack strategy.

Solar Energy for Fire & Code Officials

Firefighter Concerns – FAQ from Firefighters

Q: Can water be applied to PV without damaging them?

A: From a garden hose .. yes. From a fire hose .. maybe. A directed stream full force on the front of a PV module may shatter the glass.

Q: Should I be concerned about ventilating in the vicinity of a PV array?

A: Yes. Wiring from PV arrays is required to be run sufficiently below the roof to provide a safe distance for ventilating. Requiring it doesn't mean the margin exists.

Comment: Wiring run below the roof deck is required by NEC Article 690 to have labels installed directly above the wiring on the roof-side of the deck. In a fire, these markings may get burned away .. but the metal tabs will remain as an indicator of the solar wiring beneath the decking.

Solar Energy for Fire & Code Officials

Firefighter Concerns – FAQ from Firefighters

Comment: Check meter boxes or disconnects for a 24/7/365 emergency contact number so incident commanders can get a technician on scene ASAP to disconnect circuits if needed.

Comment: When the system is inspected and approved, the Fire Department should be given a copy of the system plans for their records to identify the location as “solar”, and to show the elements of the equipment at the site.

Solar Energy for Fire & Code Officials

Firefighter Concerns – Array Mounting Methods on Tile Roofs

Horizontal Rail Mount

Vertical Rail Mount

Photo Credit: Solar Pro Magazine

Solar Energy for Fire & Code Officials

Firefighter Concerns – Array Mounting Methods on Standing Seam Roofs

Standing seam metal roof.

S-5 Corporation standing seam clamp.

Photo Credit: S-5 Corporation www.s-5.com

Solar Energy for Fire & Code Officials

- Brief History & Overview of Solar Energy with Definitions
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Solar Energy for Fire & Code Officials

Inspecting Systems for Code Compliance

A Comment About "Compliance“:

To be in compliance with the National Electric Code, all PV must be certified to the UL 1703 Safety Standard. Inverters and other electrical hardware must be certified to the UL 1741 Standard by any of several Nationally Recognized Testing Laboratories.

Here are the most common four:

c UL us LISTED Underwriters Laboratories ("UL")	c ETL us LISTED Intertek Intertek ("ETL")
CSA C US Canadian Standards Association ("CSA")	TÜV SÜD Production monitor Safety tested TŰV

Despite decades of education, some inspectors still don't recognize any lab other than "UL".

GO SOLAR

Solar Energy for Fire & Code Officials

Inspecting Systems for Code Compliance – Common Problem Areas

- Insufficient conductor ampacity and insulation – wiring undersized for the current, or the insulation type is not designated for hot locations. Rooftops substantially exceed 90° F.
- Excessive DC voltage drop because of long distances to inverter.
- Unsafe wiring methods – inexperience by the installer.
- Lack of (or improper placement of) over-current protection and disconnect devices.

Solar Energy for Fire & Code Officials

Inspecting Systems for Code Compliance – Common Problem Areas

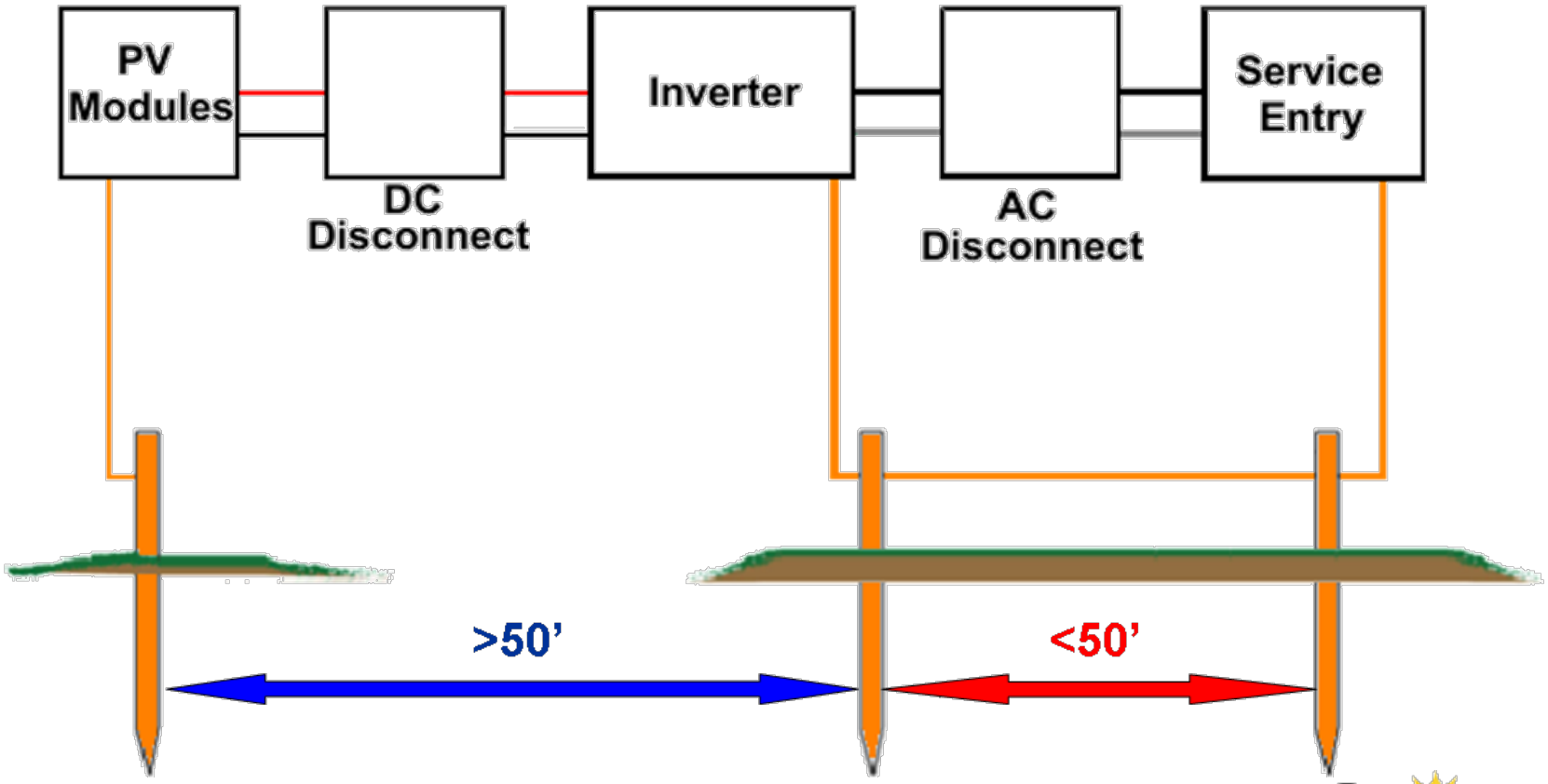
- Use of unlisted or improper application of Listed equipment (i.e., “AC” in “DC” use).
- Unsafe installation and use of batteries.
- Improper mounting and connection of equipment and racks.
- Lack of, or improper, equipment or system grounding.

A note about protective earth .. (per outside request)…

Solar Energy for Fire & Code Officials

Inspecting Systems for Code Compliance – Grounding

A single-point of earth ground strongly recommended. Multiple grounding electrodes within ~50 feet should bonded together. Consult NEC Articles 250 and 690 for proper grounding methods.



Solar Energy for Fire & Code Officials

Inspecting Systems for Code Compliance

PV Safety Standards are NOT Performance Standards.

☼ **UL 1703** – Flat-plate Photovoltaic Modules.
Electrical, as well as fire and flammability ratings, snow load ratings, wind survival, and hail. Hail Rating: Minimum 1" hailstone @ 55 mph. Solar panels are now also classified for fire rating, A through C.

☼ **UL 2703** – Rack Mounting Systems and Clamping Devices for Flat-plate Photovoltaic Modules, including integral grounds.

☼ **UL 1741** – Inverters, Switches, and other Electronics.
(Soon to be UL 62109, a "super-set" of UL 1741.)

Note: UL 62109 does not supersede nor render obsolete UL 1741. It contains additional testing requirements for international applications. Certification to either Standard is acceptable in the USA.

Solar Energy for Fire & Code Officials

Inspecting Systems for Code Compliance – A Note About Inverters

Ungrounded Inverter:

- An inverter without system grounding and without a transformer. There is no grounded current carrying conductor on and ungrounded inverter.

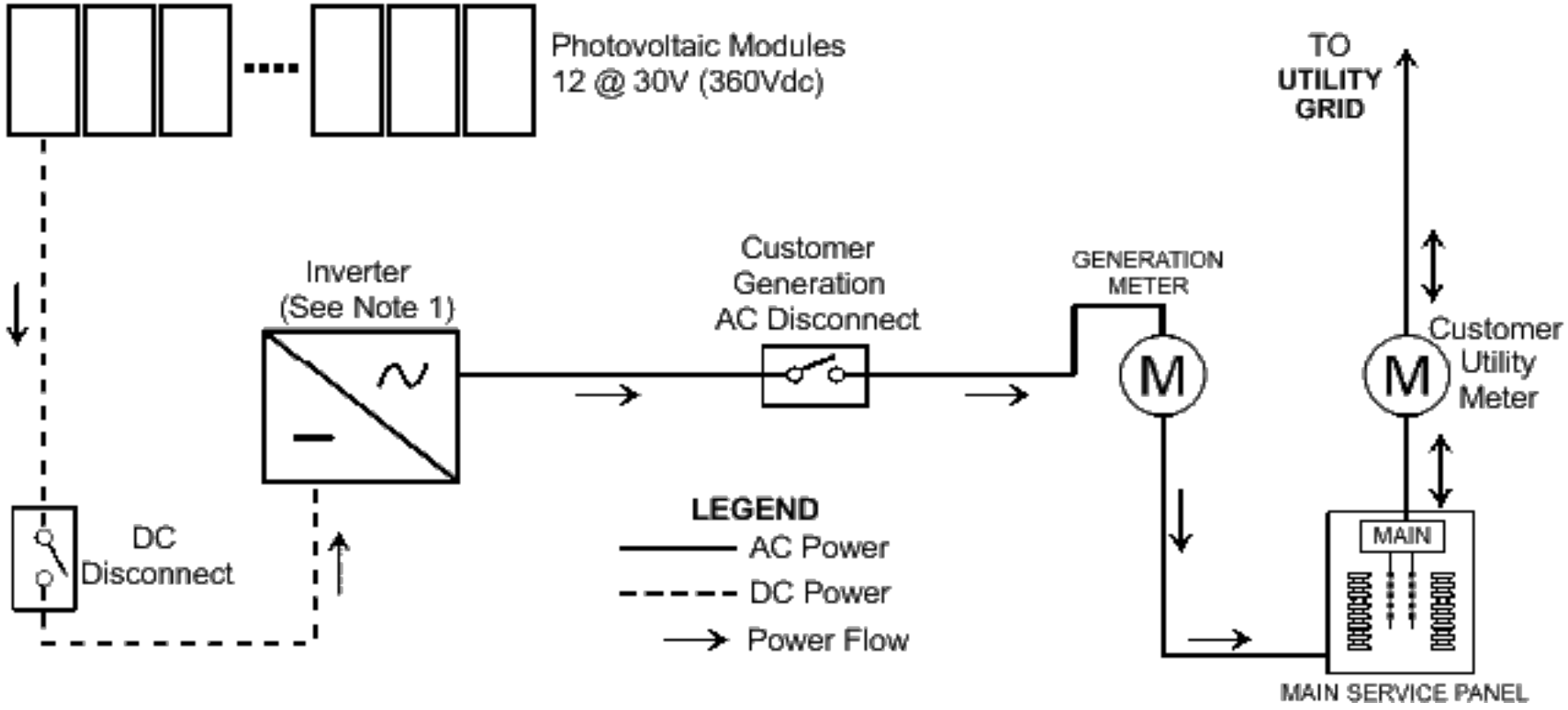
- Ungrounded inverters are also known as transformerless (“TL”) Inverters or “non-isolated” inverters. Ungrounded inverters are safer according to most experts, more efficient, and less expensive than grounded inverters.

- Ungrounded inverters are the most popular inverters installed today. (Grounded inverters were the most popular inverters in North America until about 2012).

Solar Energy for Fire & Code Officials

Inspecting Systems for Code Compliance – LOAD-SIDE Connection

Basic one-line diagram. Some required details and components, as well as earth ground, have been omitted for simplicity.



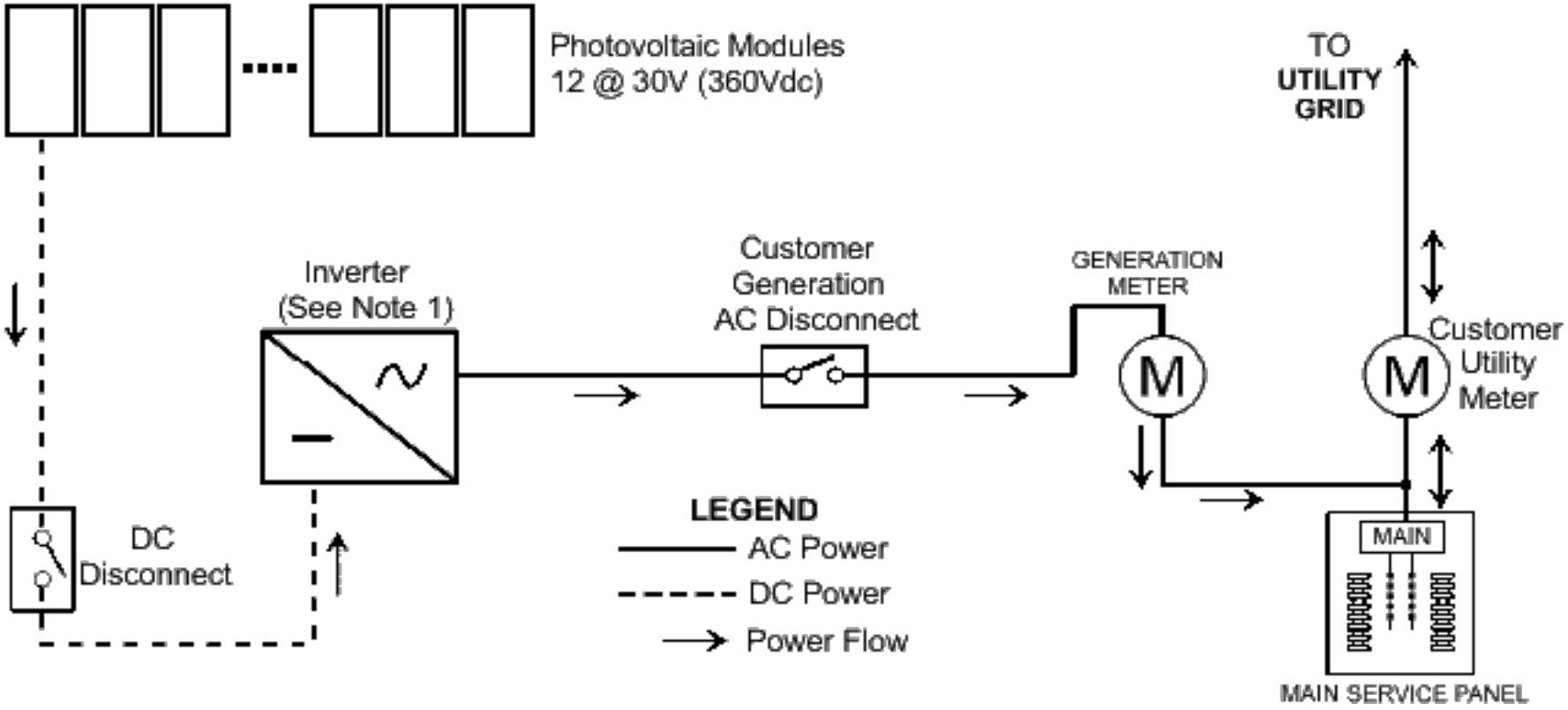
"**Load-side**" for <=20% of the service panel buss amperage rating.

GO SOLAR

Solar Energy for Fire & Code Officials

Inspecting Systems for Code Compliance – LINE-SIDE Tap

Basic one-line diagram. Some required details and components, as well as earth ground, have been omitted for simplicity.



"**Line-side**" for >20% of the service panel buss amperage rating.

Solar Energy for Fire & Code Officials

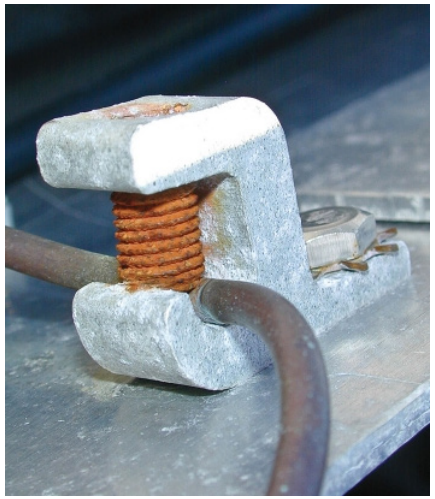
Inspecting Systems for Code Compliance – NEC Article 690

- 690.2 … Definitions
- 690.4 … Installation
- 690.5 … Ground Fault Protection
- 690.7 … Maximum Voltage
- 690.8 … Circuit Sizing & Current
- 690.9 … Overcurrent Protection
- Section III … Disconnecting Means
- Section IV … Wiring Methods
- Section V … Grounding
- Section VI … Marking

Solar Energy for Fire & Code Officials

Inspecting Systems for Code Compliance – NEC Article 690.4

- Conductors of Different Systems: PV DC circuits, must be separated from AC wiring by a partition or plenum unless the wires are electrically connected to the same circuit, such as a grounding conductor.
- Module Disconnection: Removing a PV module in a source circuit shall not interrupt the ground to other PV modules.
- Grounding hardware shall be certified for underground burial and use in wet locations. Stainless steel hardware, not zinc or tin-plated.



Solar Energy for Fire & Code Officials

Inspecting Systems for Code Compliance – NEC Article 690.5

- If it's mounted on the roof of a residential or other structure, it must have DC ground-fault protection.

- Labels & Marking must warn of potential for energized and ungrounded conductors that are normally grounded.

Solar Energy for Fire & Code Officials

Inspecting Systems for Code Compliance – NEC Article 690.7

- Maximum PV System Voltage: Source or Output circuits rated at sum of series V_{OC} multiplied by correction factor for lowest ambient temperature from the table. All conductors, components, and devices in the DC circuit must be rated for this voltage or higher.

Solar Energy for Fire & Code Officials

Inspecting Systems for Code Compliance – NEC Article 690.7

- Circuits over 150 VDC to Ground: In 1 & 2 family dwellings, energized parts must be accessible to qualified persons only, and require a tool to open.

Solar Energy for Fire & Code Officials

Inspecting Systems for Code Compliance – NEC Article 690.8

- Maximum Source Circuit Current: Sum of parallel I_{sc} x 1.25 in source circuit.
- Maximum Output Circuit Current: Sum of parallel connected Max Source Circuit Currents.
- Inverter Output Circuit Current: Continuous output current rating. (e.g. a 2.5 kW inverter with only 1 kW PV array connected is still rated 2.5 kW).
- Conductors and DC Overcurrent Devices: Must be rated to carry maximum output circuit current x 1.25. This is called the "1.56 Rule". (1.25 x 1.25 = 1.56).

Solar Energy for Fire & Code Officials

Inspecting Systems for Code Compliance – NEC Article 690.8

- Internal Current Limitation: If internally current-limited devices are in circuit, you only need to multiply parallel I_{sc} x 1.25.
- Multiple DC Systems: Multiple output DC systems with common return/neutral conductors shall have that conductor rated to carry the sum of all circuit amperage.
- Sizing Module Interconnect Conductors: Must be sized to carry entire parallel-connected circuit.

Solar Energy for Fire & Code Officials

Inspecting Systems for Code Compliance – NEC Article 690.9

- Circuits and Equipment: All hardware in DC circuits must have over-current protection.
- PV Source Circuits: Allows standard over-current protection devices and ratings to be used, and requires accessibility, but not “readily accessible”.
- DC Rating: Requires applicable DCV rating of devices.
- Series Over-Current Protection: Allows single over-current protection device per string when more than 2 strings are connected in parallel.

Note: When only one PV string is present, or two PV strings are connected in parallel, an over-current protection device is not required.

Solar Energy for Fire & Code Officials

Inspecting Systems for Code Compliance – NEC Article 690.9

- Utility power can have very high momentary short-circuit current.
- PV source circuits do NOT have this same high-current capability.
- Source-circuit overcurrent protection devices must be appropriately rated for current, voltage, AND for DC operation in PV source circuits.
- Over-current protection devices must be rated for 125% of the PV current to account for times when irradiance may exceed 1,000 watts per square meter.

Solar Energy for Fire & Code Officials

Inspecting Systems for Code Compliance – NEC Article 690, Section III

- All Conductors: Requires means of disconnecting all current-carrying PV conductors from other conductors.
- Disconnecting Means: Not required to be rated as Service Equipment.
- Equipment: Allows over-current protection, diodes, and isolation switches on PV-side of the disconnect.

Solar Energy for Fire & Code Officials

Inspecting Systems for Code Compliance – NEC Article 690, Section III

- Disconnecting Means: Location must be readily accessible without assistive means (ladder, etc.).
- Attics and roofs do not qualify as “readily accessible”.
- Marking: Must be permanently marked as PV system disconnect.
- Suitable for Use: Must be rated for prevailing conditions. (i.e. If outside, must be rain tight, such as NEMA 3R.)

Solar Energy for Fire & Code Officials

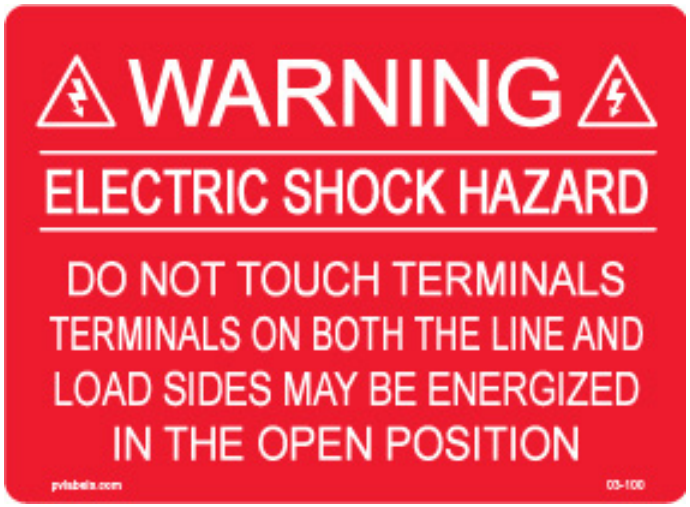
Inspecting Systems for Code Compliance – NEC Article 690, Section III

- Maximum Disconnects: No more than 6 disconnects.
- Grouping: Disconnects must be grouped together.
- Disconnection of PV Equipment: All equipment must be able to be disconnected from other sources.

Solar Energy for Fire & Code Officials

Inspecting Systems for Code Compliance – NEC Article 690, Section III

- Switch or Circuit Breaker: Requires readily accessible, externally operable, ON-OFF indication, rated for maximum system voltage and current. If all terminals may be energized with switch in the open position, special marking is required.



Solar Energy for Fire & Code Officials

Inspecting Systems for Code Compliance – NEC Article 690, Section IV

- Wiring Systems: Allows standard wiring methods and materials, as well as PV-specific.
- Single Conductor Cable: Allows SE, UF, USE and USE-2 to be used if installed like UF. Note: UF cable may not have an adequate temperature rating.
- Flexible Cords & Cables … for moving parts of tracking systems.

Solar Energy for Fire & Code Officials

Inspecting Systems for Code Compliance – NEC Article 690, Section IV

- Correction Factors: Gives factor for de-rating the ampacity of conductor rating based on temperature. Small-conductor cables. Allows 16 and 18 AWG sunlight & moisture resistant cables for module interconnection provided they're rated for the amperage and temperature of the parallel connected circuit.

- Component interconnections: Requires field-assembled components to be equal to the rest of the system.

Solar Energy for Fire & Code Officials

Inspecting Systems for Code Compliance – NEC Article 690, Section IV

Determining the Correct Current Value for Conductors:

- Photovoltaic source circuits are rated by the sum of their short-circuit current value, multiplied by 125%.

- Why 125%? Sometimes more than 100% "normal" irradiance occurs. Irradiance = sunlight intensity". PV current increases proportionately with irradiance.

- Conductors must be sized to handle this higher current.

Solar Energy for Fire & Code Officials

Inspecting Systems for Code Compliance – NEC Article 690, Section IV

- ☼ Connectors: Not interchangeable with other premises types, and must be polarized. Must prevent live-part contact. Latching or locking. 1st to "make" and last to "break" ground conductor.

Note: Some "PV" connectors appear to be compatible across different brands. This is NOT the case. Connector brands should not be mixed in PV source circuits.

Solar Energy for Fire & Code Officials

Inspecting Systems for Code Compliance – NEC Article 690, Section V

Section V Does NOT Replace Article 250.

- System Grounding: Requires grounded DC conductor for galvanically-isolated transformer-based inverters. Allows ground-fault protective device to accomplish grounding.
- Point of System Ground: Single point at service entry.
- Equipment Ground: All exposed dead metal must be connected to protective earth ground.
- Size of Equipment Ground Conductor: No GFP means 125% of the source circuit Isc. GFP allows sizing to NEC Table 250.122 based on over-current protection rating.

Solar Energy for Fire & Code Officials

Inspecting Systems for Code Compliance – NEC Article 690, Section V

- Grounding Electrode System… AC & DC system grounding electrodes must be bonded together at some point. Recommends that no more than 1 electrode per system be installed. If a separate equipment grounding electrode is present, it should be connected to the system ground.

- DC Systems: Must not be smaller than largest system conductor or #8 AWG CU … whichever is larger. [Reference NEC 250.166]

Solar Energy for Fire & Code Officials

Inspecting Systems for Code Compliance – NEC Article 690, Section VI

- Modules: Lists ratings that must be marked on modules. (Manufacturer label.)
- PV Power Source: States ratings that must be provided at the PV DC disconnect by the installer.
- Interactive System Point of Interconnection: Requires AC current and voltage to be posted.
- Facilities with utility and PV: PV system disconnect location must be posted at utility service disconnect and PV system disconnect if not located together.

Solar Energy for Fire & Code Officials

Inspecting Systems for Code Compliance – NEC Article 690, Section VI

Incorrect and inadequate labeling is one of the most common reasons a photovoltaic system fails to pass inspection.

Key Points:

All required labeling is detailed in the NEC, Articles 690 and 705.

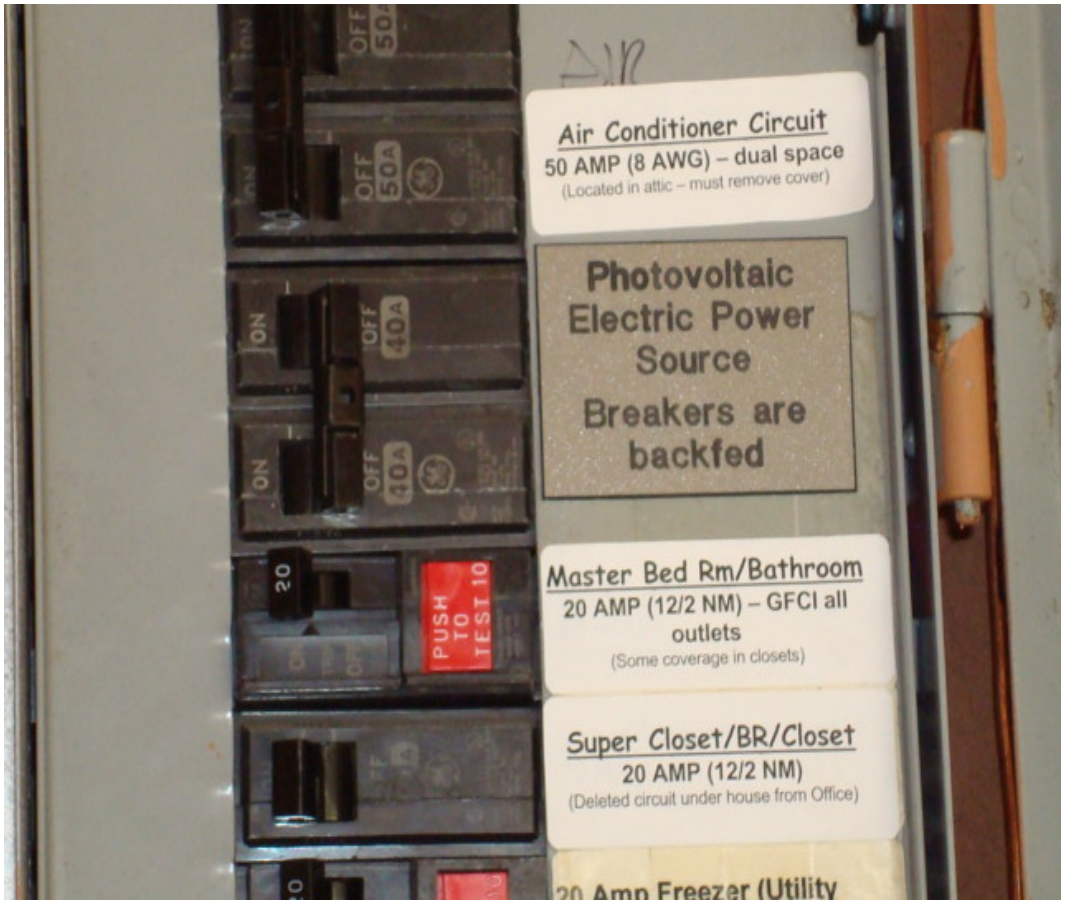
Not only all locations where labels are required, but also:

- Type and Color of Label Materials
- Wording and Symbols on Labels
- Label Attachment Methods Permitted and Required
- Labels must meet the UL 969 Standard for Safety Marking.

Large commercial / industrial / utility scale systems have additional marking and labeling requirements.

Solar Energy for Fire & Code Officials

Inspecting Systems for Code Compliance – NEC Article 690 - Panelboard



Solar breaker amperage, or the sum of solar breaker amperages, may not exceed 20% of the panel service buss amperage rating.

Note: Main breaker may be down-sized to allow for more solar amperage on the buss.

Solar Energy for Fire & Code Officials

Inspecting Systems for Code Compliance – NEC Article 690 - Miscellaneous

- Photovoltaic DC and AC circuits are not “load” circuits.
- Photovoltaic systems generate current – not consume it.
- For code purposes, all PV system DC and AC source circuits are considered “continuous”.

Solar Energy for Fire & Code Officials

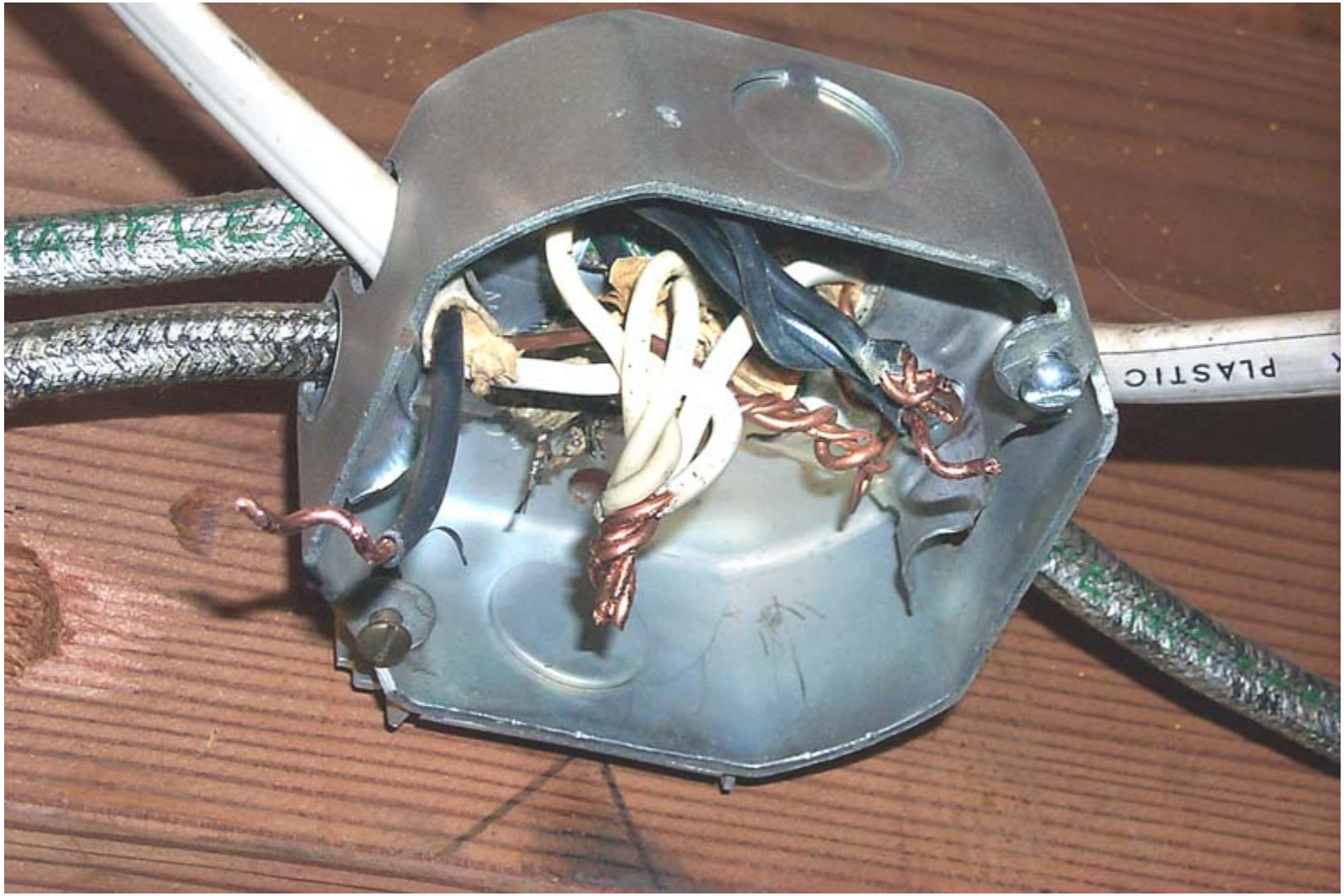
Inspecting Systems for Code Compliance – NEC Article 690 - Miscellaneous

- Texas law requires a TDLR-licensed Master Electrician to supervise and have oversight of solar-electric installations.

- Having a Master Electrician's license does not mean the license holder knows or understands anything about solar electric circuits, equipment, or requirements.

Solar Energy for Fire & Code Officials

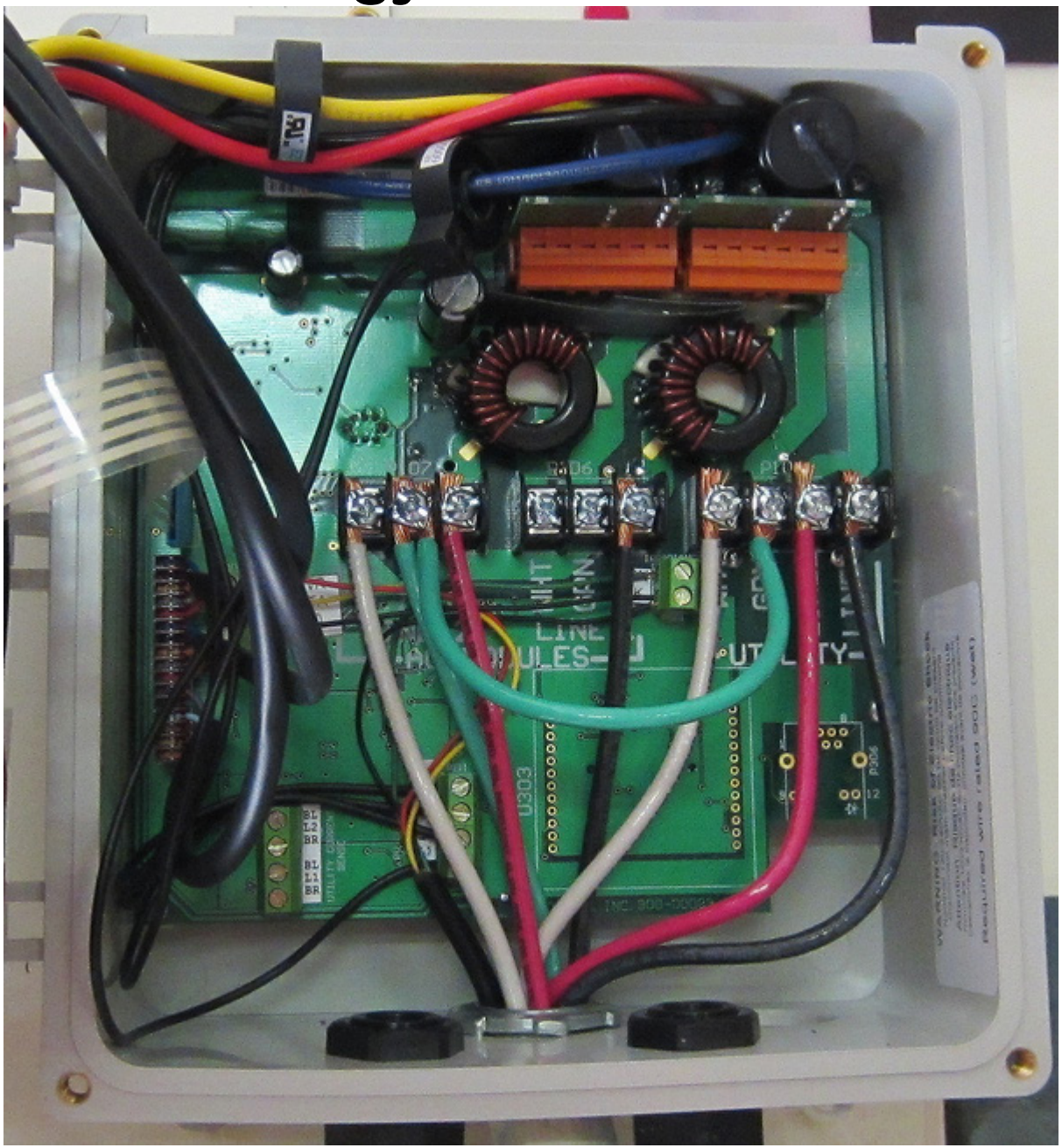
“How Not To…”



(Example NOT from a “solar” installation)

GO SOLAR

Solar Energy for Fire & Code Officials



What's wrong here?

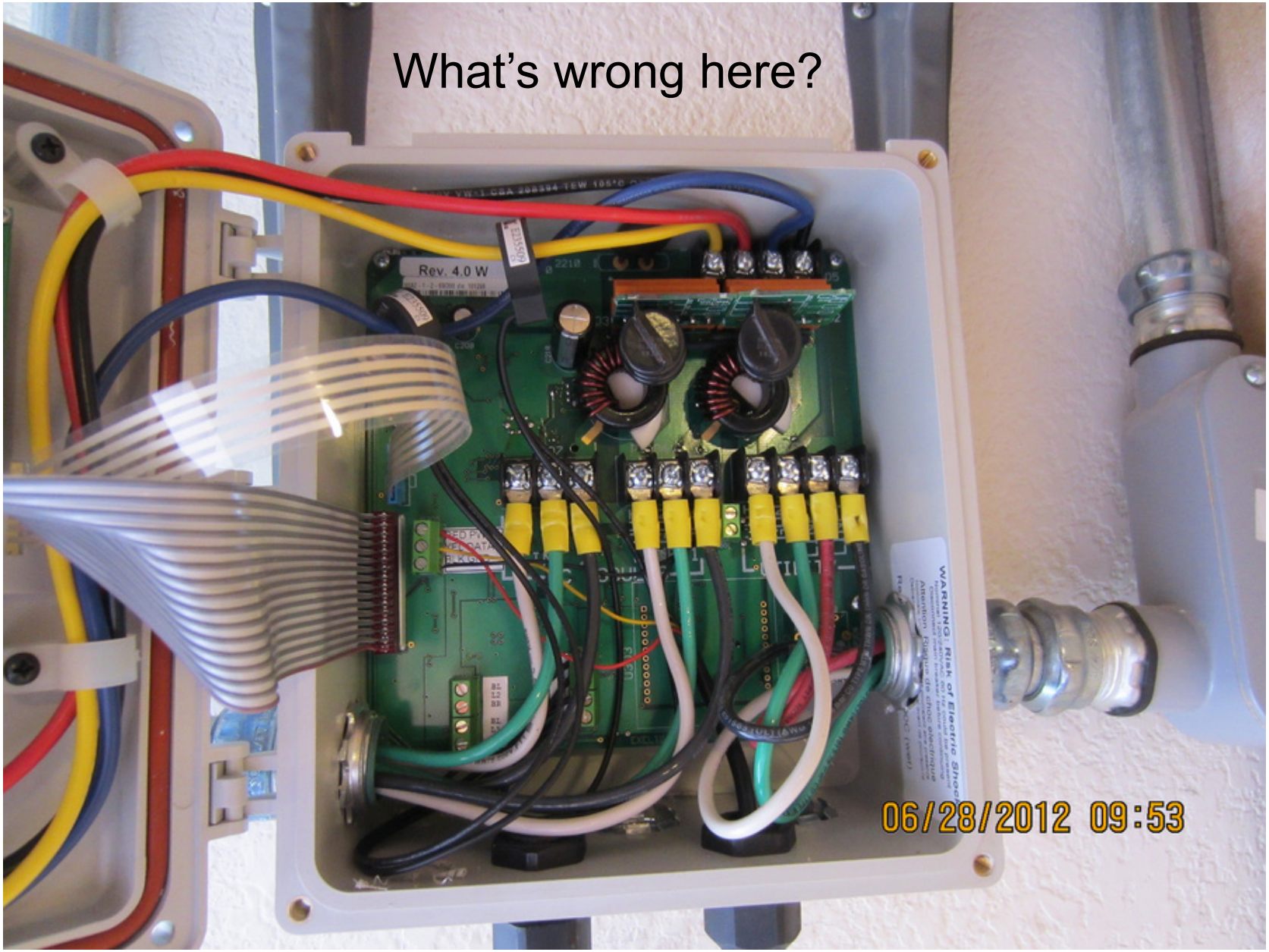
Utility ground is attached to the left-most connector.

This is marked as an **input** from the solar AC.

Instructions direct installers to attach the utility ground to the **utility** connector – on the right (clearly labeled!).

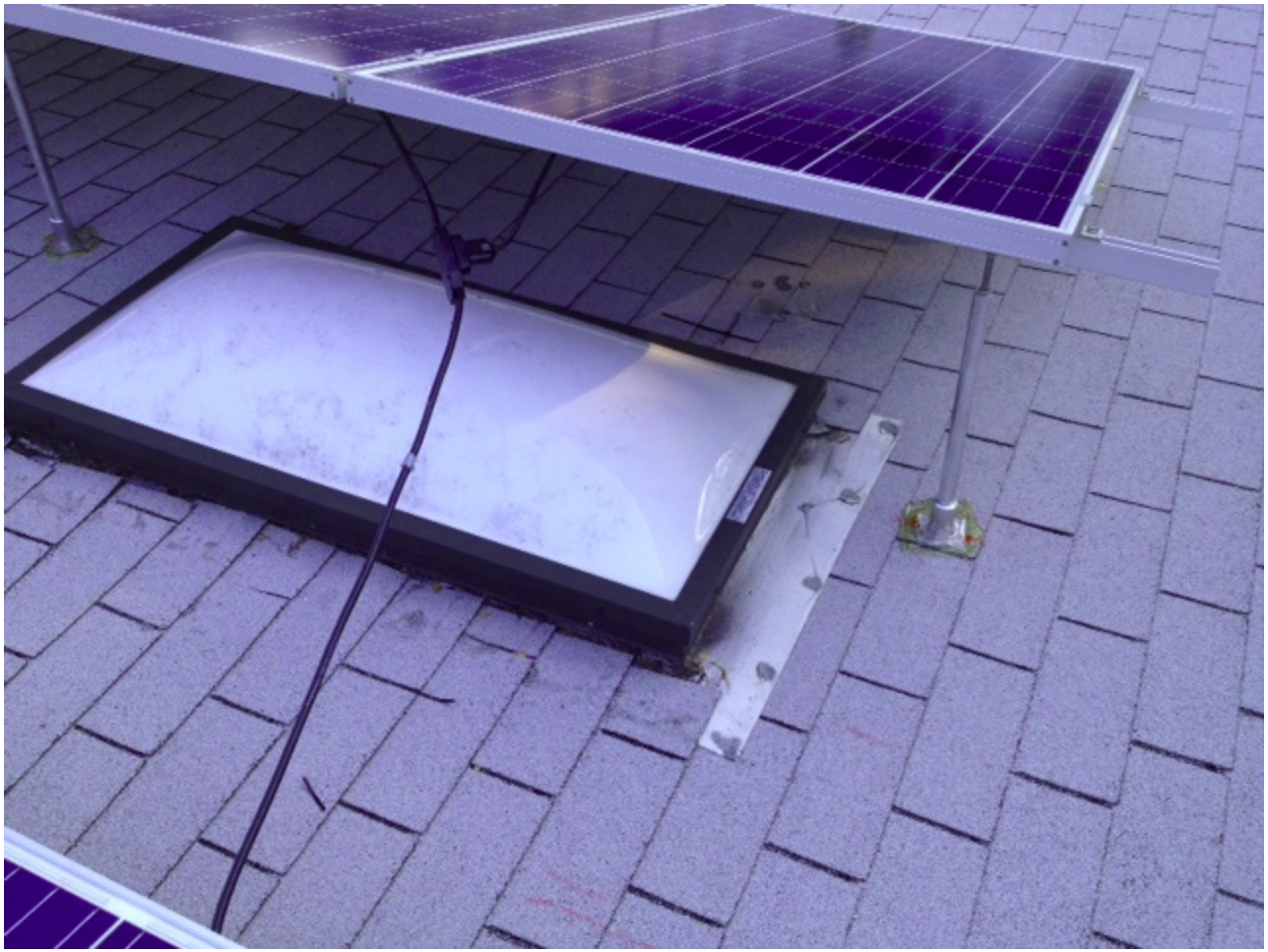
Moreover, the utility ground is essentially spliced – a Code violation.

Solar Energy for Fire & Code Officials



Solar Energy for Fire & Code Officials

“How Not To…”



What’s wrong here?

Solar Energy for Fire & Code Officials

“How Not To…”

What’s wrong here?

Solar Energy for Fire & Code Officials

“How Not To…”

What’s wrong here?

Solar Energy for Fire & Code Officials

“How Not To…”

What’s wrong here?

Solar Energy for Fire & Code Officials

“How Not To…”

What’s wrong here?

Solar Energy for Fire & Code Officials

“How Not To…”

What’s wrong here?

Solar Energy for Fire & Code Officials

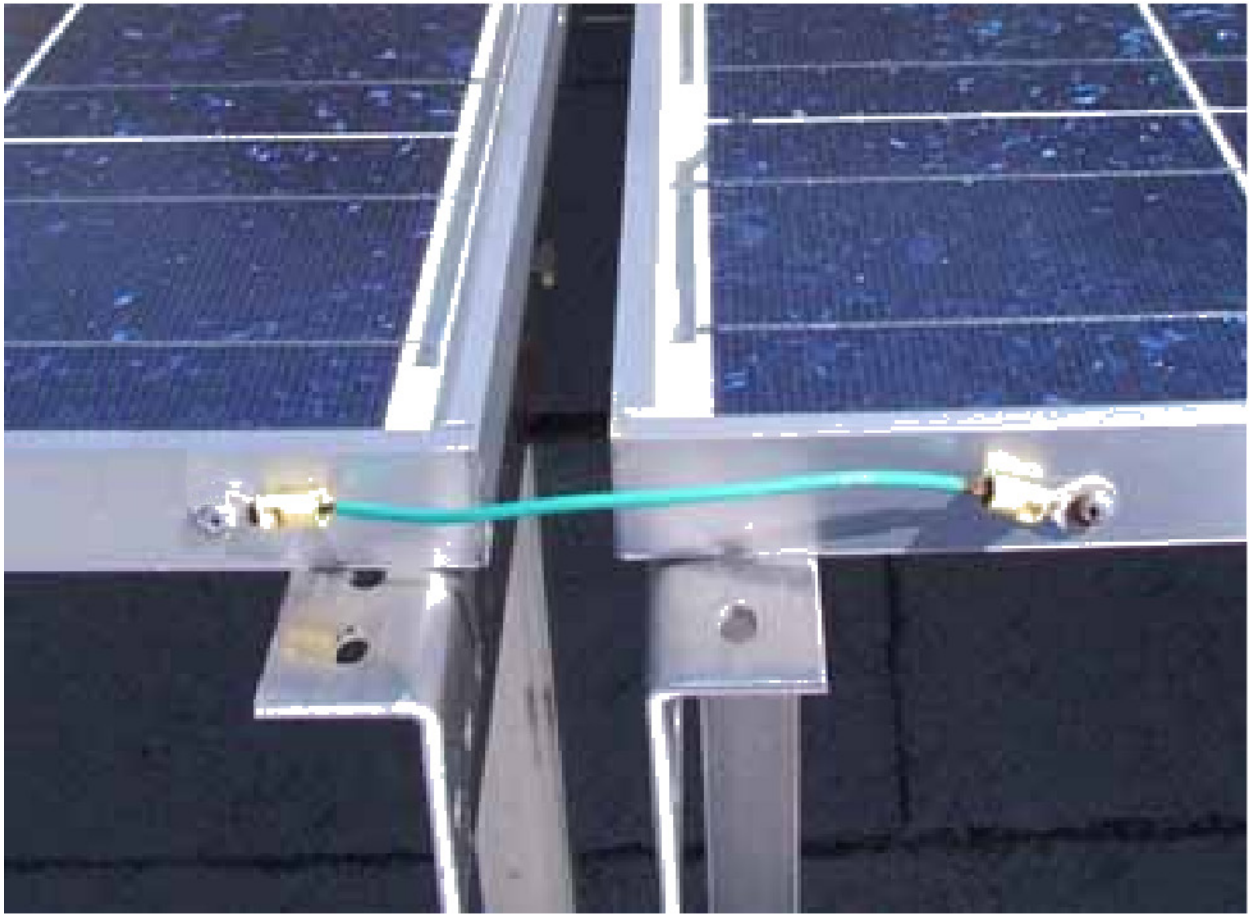
“How Not To…”

What Happened Here?

Two dissimilar metals such as copper and aluminum in direct contact will experience a "galvanic reaction", corroding each other, leading to potentially dangerous conditions.

Solar Energy for Fire & Code Officials

“How Not To…”



What’s wrong here?

Solar Energy for Fire & Code Officials

“How Not To…”

Why a Professional Structural Engineer is required to evaluate and pre-approve roof strength of any commercial PV system.

Solar Energy for Fire & Code Officials

“How Not To…”

What’s wrong here?

GO SOLAR

Solar Energy for Fire & Code Officials

"How Not To…"

Enclosure
(DC Combiner)

Enclosure
(DC Disconnect)

What's wrong here?

Solar Energy for Fire & Code Officials

“How Not To…”

Enclosure
(DC Combiner)

What’s wrong here?

Solar Energy for Fire & Code Officials

“How Not To…”

No Comment.

Solar Energy for Fire & Code Officials

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Solar Energy for Fire & Code Officials

Changes Pending in the 2017 National Electric Code, NFPA70

GO SOLAR

Solar Energy for Fire & Code Officials

690.1 Removes large-scale PV from the scope of Article 690. Revised figures clarify the "end-point" of a PV system.

690.2 New and revised definitions for DC-to-DC circuit, PV system DC circuit, generating capacity, inverter input/output circuit, and "functional grounded PV system".

690.4[D] Clarifies multiple PV systems, not just multiple inverters, are allowed on a single building.

690.5 and 690.35[C] Moved to 690.41[B]. Consolidates grounding and ground-fault protection issues.

Solar Energy for Fire & Code Officials

690.7 Reorganized, and adds a voltage calculation method for larger PV systems.

690.8 Revised to cover DC-to-DC converter circuits. Allows for additional calculation method for PV circuit currents.

690.9 Revised to cover all PV systems including ungrounded systems. Requires only one over-current device per circuit.

690.10 Stand-alone PV systems - moved to new Article 710.

Solar Energy for Fire & Code Officials

690.11 Exempts ground-mounted PV system circuits from arc-fault protection in some cases.

690.12 Dramatically increases details in 690.12 and includes requirements for rapid shutdown within the array.

690.12(B)(2) shall become effective January 1, 2019.

690.13 Clarifies there are only two types of disconnects in PV systems:
1) The PV system disconnecting means (690.13), and;
2) The disconnects for equipment (690.15).

Solar Energy for Fire & Code Officials

690.31 Reorganized and revised. Single set of requirements cover all wiring methods, including ungrounded systems.

590.31[B][1] Disallows use of white wire on the DC-side of a PV system for anything except solidly grounded PV systems, which are rare.

690.31[C][1] Type USE-2 and PV wire are now permitted as single-conductor cable for grounded and ungrounded PV systems.

690.31[D] Requires multi-conductor cables be Listed for the application.

Solar Energy for Fire & Code Officials

690.41 & 690.42 Introduces the concept of "functional grounded PV systems" to Article 690. Requires ground-fault protection for all PV systems that are not solidly grounded (the vast majority of systems).

690.43 Reorganized for clarity. Simplifies equipment grounding requirements.

690.47 Completely reorganized and simplified. Requires metal support structures to have grounding electrode system. Requires ground conductor be connected to the local grounding electrode system. Make additional array electrodes optional.

Solar Energy for Fire & Code Officials

690.53 Simplifies DC PV source marking by removing rated maximum power point voltage and current from signage.

690.56[C] Details marking requirements for systems equipped with rapid shutdown.

Part VII Simple reference to Article 705 replaces Part VII, "Connection to Other Sources."

Parts IX and X Removes content about systems over 1,000 volts and electric vehicle charging. These are now covered elsewhere.

Solar Energy for Fire & Code Officials

ARTICLE 705

705.2 Adds a definition for “micro-grid”.

705.12 Simplifies the entire section to cover just supply-side and load-side interconnections.

705.12[B] Allows for the load-side interconnection of other equipment besides inverters.

Solar Energy for Fire & Code Officials

705.12[D][6] Removes arc-fault detection requirement for small AC circuits.

705.23 New section to match the changes in Article 690 related to the PV system disconnecting means.

Part IV Adds new part dedicated to micro-grid systems.

Solar Energy for Fire & Code Officials

The 2017 Edition of NFPA 70 National Electrical Code, substantially changes the practical safeguards for PV systems. It introduces more changes to Article 690, “Solar Photovoltaic (PV) Systems”, than any revision cycle since 1984, when the NEC first adopted Article 690.

From a statistical perspective, the word count in Article 690 has been reduced in the 2017 Code by more than 20% vs. the 2014 Code, from nearly 11,000 words in 2014 to just over 8,000 words in 2017.

Rapid-shutdown aspects in Section 690.12 increased 900% from 133 words in 2014 to more than 1,100 words in 2017.

Disclaimer: The National Fire Protection Association (NFPA) will not formally adopt NEC 2017 until its Technical Meeting, June 16, 2016. However, the development process is substantially complete. Therefore, excerpts herein are unlikely to vary substantially from the published draft. It’s anticipated the NFPA will begin shipping NEC 2017 in October 2016.

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QUESTIONS?

Join Us!

Summer Solar Webinar Series

Community Solar in Texas, 11:30 am, Friday, July 8

This webinar will focus on providing information to electric utility cooperatives and municipal owned utilities who may be interested in exploring opportunities for community solar programs. Presentations will discuss ownership structures, financing options, and marketing and outreach needs.

Putting Underutilized Land to Work, 11:30 am Wednesday, July 27

This webinar will focus on providing information to local governments including school districts, special districts, and business/industry sectors interested in going solar. Presentations will include topics such as solar applications on landfills, brownfields, wastewater treatment plants, and other facilities where Solar PV can be put to work for energy savings.

Visit gosolartexas.org for webinar details

Thank You!

Presentations, upcoming webinars and training opportunities posted at GoSolarTexas.org

<u>Training Contact:</u>
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Thank You!

Presentations, upcoming webinars and training opportunities posted at GoSolarTexas.org

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Your Presenter…

Dan Lepinski, P.E. - Professional Consulting Engineer in Solar & Power Industries.
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- **Voting Member** - Underwriters Laboratories UL 1741 Standards Technical Panel.
  Author the UL 1741 Safety Standard for the entire solar energy industry.

- Member - Solar Industry Task Force to the National Fire Protection Association.
  NFPA publishes the National Electric Code, NFPA 70.

- Member - Solar America Board for Codes and Standards.
  Interface with and advise the NEC Task Force and UL 1741 STP.

- Member - Electric Power Research Institute "Smart Grid" Development Committee.
  Engineers, scientists, experts from academia & the industry address challenges in electricity.

- Professional Consultant with Intertek / ETL.
  Intertek / ETL is one of several Nationally Recognized Testing Laboratories certified by OSHA to test products to the UL Safety Standards.

- Master Instructor for "NABCEP" - the American Certifying Body for solar energy system designers and installers ensuring code and safety compliance.

- 44 years in the solar energy industry .. and still active!

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