Alternative Energy Systems

Based on the 2017 NEC

Presented for

PennBOC

by

Jeff Bower

Objectives

- Name the sub-components of solar systems.
- Describe how to size various components of the solar system.
- Describe different types of solar systems.
- Describe the labeling requirements of solar systems.
- Describe what rapid shutdown is and when it is required.
- Explain the building code requirements for access.
- Explain how solar systems are rated.
- Explain code requirements for electrical install of PV Systems.

System Components

- Solar Cell
- Module
- Panel
- Array, Sub-array, or PV Source
- PV Source Circuit
- Fuse
- DC-DC Converter (Optimizer)
- DC-DC Converter or PV Output Circuit

System Components Continued

- Inverter (Interactive, Multi-mode, or Stand – Alone
- Inverter Output Circuit
- PV System Disconnect

Solar Cell and Panel

Solar Array

Fuse and DC-DC Converter

Inverter

PV System Disconnect

System Types

- Interactive System
- AC Module System
- DC Coupled Multi-Mode System
- AC Coupled Multi-Mode System
- Stand Alone System
- https://link.nfpa.org/publications/70/2017/chapters/6/articles/690

Locating and Sizing Solar PV Systems

Once Solar PV is Decided On

<u>The final PV array location is determined by;</u>

A. First and foremost no progress can be made unless the electric utility has approved the project
B. An engineer who produces drawings
C. The Service and Meter (S&M) form that was submitted to electrical utility
D. Electrical contractor (installs with modifications)
E. Homeowner/building owner (if any options left)

Types of System Tie-ins

One Meter vs Two

- PECO was always two meter set up but…
- Now using a single smart meter for 100 and 200 amp services
- PECO still requires the two meter setup for 400 amp services
- Always coordinate with whatever utility covers the area you will install in
- PPL uses a single smart meter

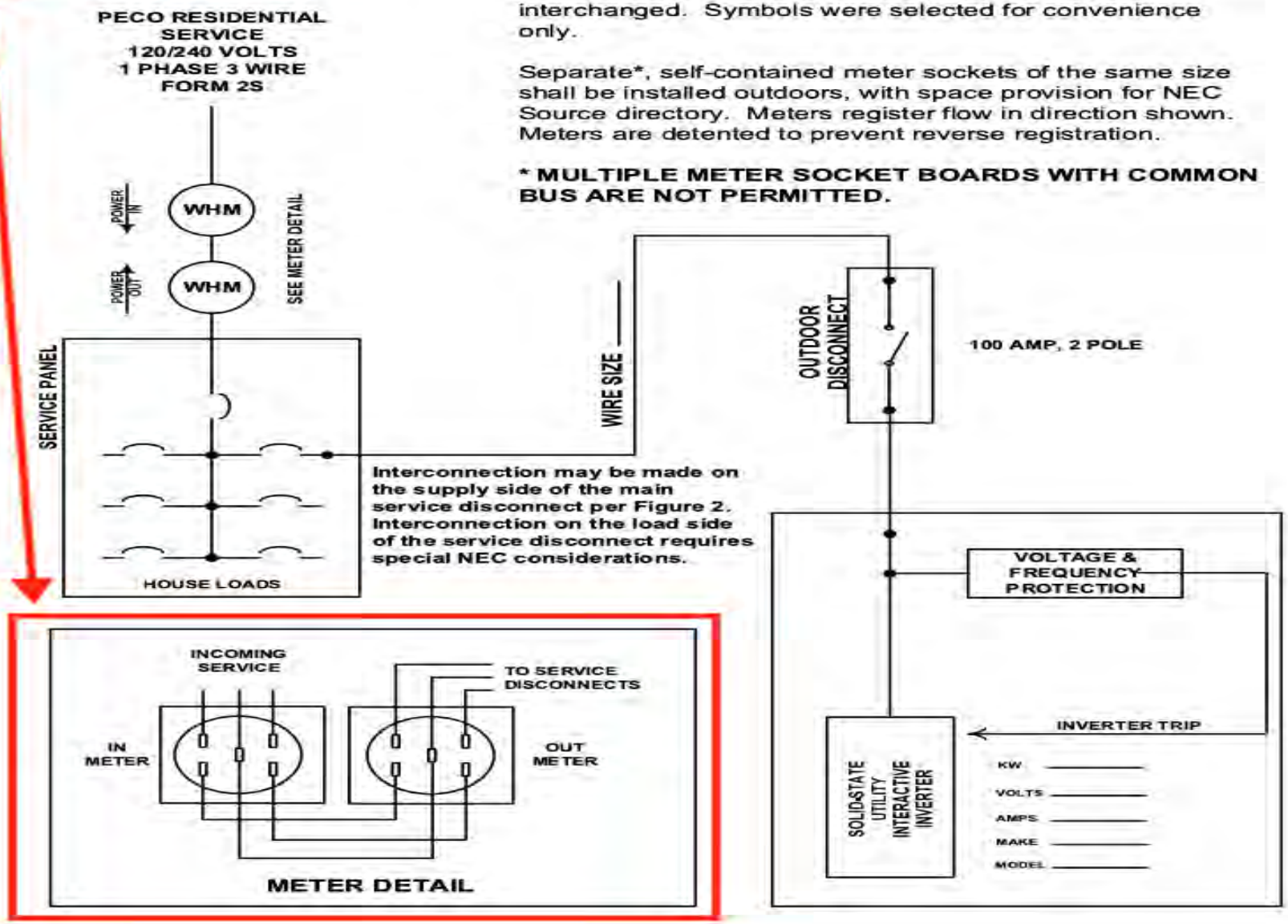
FIGURE 1
RESIDENTIAL NON-UTILITY GENERATION
TYPICAL SERVICE & EQUIPMENT ARRANGEMENT
PHOTOVOLTAIC / UTILITY INTERACTIVE INVERTER

Meters are wired in series. Bottom of "In" meter is wired to bottom of "Out" Meter

All equipment shown, except for watt-hour meters (WHM), are owned, operated and maintained by the customer. Both breakers and switch/fuse equipment may be interchanged. Symbols were selected for convenience only.

Separate*, self-contained meter sockets of the same size shall be installed outdoors, with space provision for NEC Source directory. Meters register flow in direction shown. Meters are detented to prevent reverse registration.

*** MULTIPLE METER SOCKET BOARDS WITH COMMON BUS ARE NOT PERMITTED.**



Interactive

- Use what is being generated by the PV system
- Just feed any extra back to grid if any
- Three possible locations to tie in a parallel system to the grid
  - Load side
  - Line side
  - Supply side

Stand Alone

- Just supply own needs
- Rural applications
- Remote lighting, communications
- Cabin in the Poconos
- Highway construction sites

Battery Backup System

- Use what AC is needed for regular loads
- Charge and discharge the batteries daily saves money not paid to utility
- PV power stored in batteries for emergencies
- Send excess electric back to grid
- Utility electric power is still available 24/7 if needed
- Want to be sure of available power during utility outage? Install a standby generator or …….
- Back feed electric from your Tesla or Ford F150

Electric System Parameters

- Keep all PV components as close together as possible
- All disconnects for electric utility personnel must be grouped
- Inverters are made for indoors or outdoors as most are enclosed in NEMA 3R enclosures, but you should baby them to minimize problems. Keep them dry and cool as possible for longer life
- NEMA 3R enclosures are rated for installation outdoors exposed to rain etc.
- Central inverters should be installed out of the sun
- Central inverters are relatively heavy

Solar PV Components

- Module (one panel)
- DC modules
- AC modules (Enphase)
- String (number of modules connected in series)
- DC Combiner (junction box with or without fuses)
- DC disconnect (fused or un-fused)
- Inverter (changes DC to AC)
- AC disconnect (safety switch or two-pole CB)
- Utility disconnect (for Utility personnel)
- Rapid shutdown required
- Load side tie in (two-pole circuit breaker)
- Line side tie in (ahead of CB panel)
- Supply side tie in (ahead of existing meter socket)
- Single “net” or “smart” meter vs two-meter setup

DC Module

AC Module

Module Technical Data

- Voc
- Vmp
- Isc
- Imp
- Pmp
- Module efficiency
- STC data: 25°C cell temp, 1.5 ASTM, 1000 W/sq. meter
- Cold temperature corrections NEC Table 690.7
- Refer to spec sheet supplied with module

Calculating Circuit Current

- 690.8 Contains the requirements
- https://link.nfpa.org/publications/70/2017/chapters/6/articles/690
- Maximum Voltage for 1 and 2 family dwellings is 600V DC and 1000V for other buildings per 690.7.

Solar PV Module

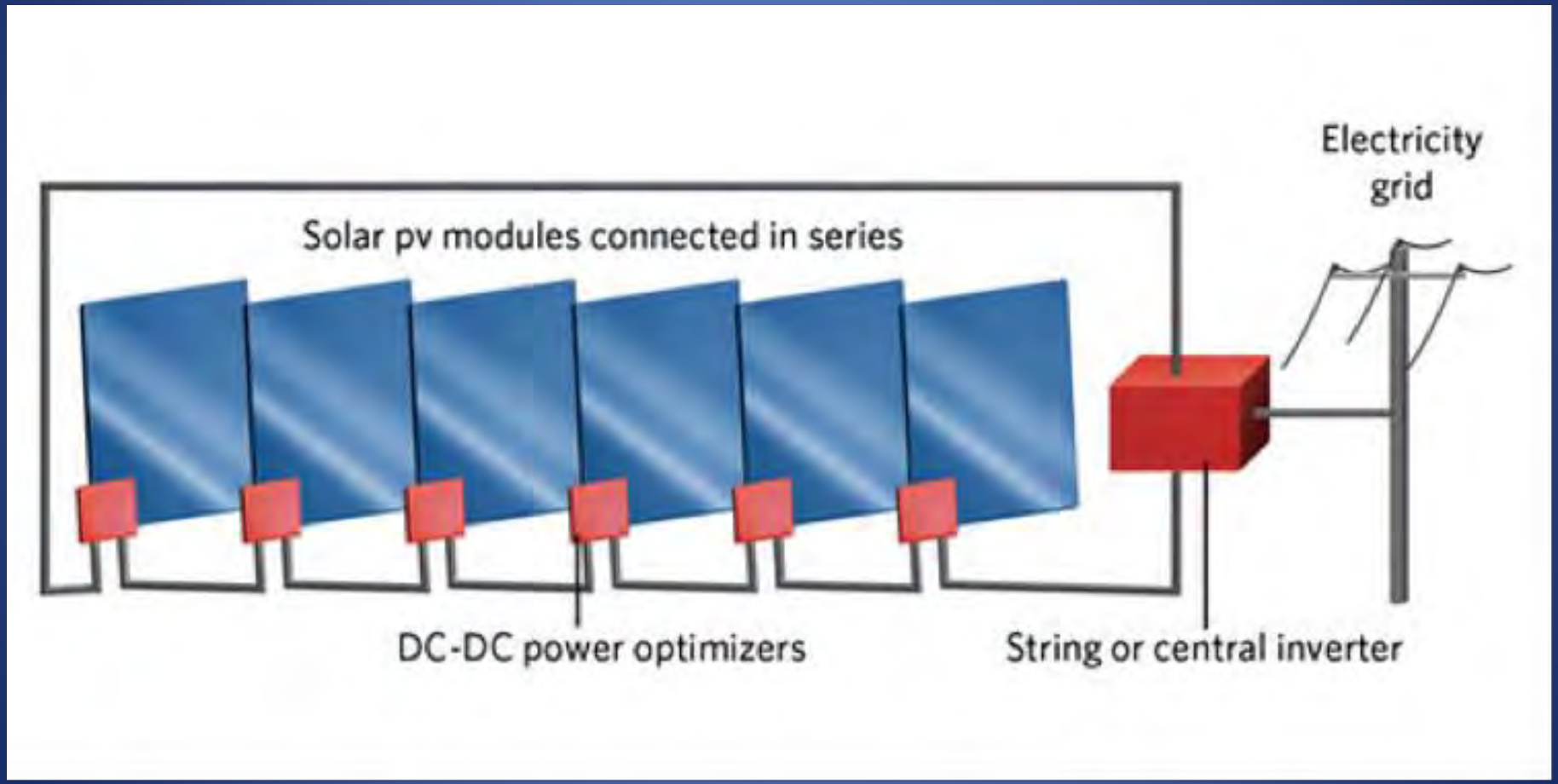
- Example: 175 W module might have a rating of 5 amps and 35 volts.
- Three modules connected in series produces 5 amps and 105 volts (3 x 35 V).
- The DC power would be 525 Watts (3 x 175 W)

PV Conductors

- After all ampacity adjustments due to;
  - Rooftop temperature
  - Number of current-carrying conductors in a raceway
- 10 AWG is the magical perfect size conductor to connect strings to the combiner
- RHH-2, RHW-2, USE-2 and PV conductor insulations are all listed for being in the open and exposed to weather
- THHN/THWN does not meet that criteria


900-8820-9473 10 AWG XLP (UL) TYPE RHH OR RHW-2 OR USE-2 600V 90C (-40C) OIL RES II

String


Electricity grid
Solar pv modules connected in series
DC-DC power optimizers
String or central inverter

String

- A string is a lineup of modules connected in series.
- A string might contain anywhere from 8 to 15 modules for example
- Each string is then individually fused
- Ten of our sample modules rated at 5 amps and 35 volts connected in series in one string would still produce 5 amps but the voltage is now 350 Volts DC and the total watts is 1750.

Eight-module Strings

String Calculation Sheet

- In series connection the voltage will add and the amperage remains the same

- When connecting strings in parallel the amperage will add the and the voltage level remains the same
- The NEC requires that the cold weather factor be used to determine the maximum open circuit voltage of a string of modules. In Philadelphia the multiplier would be around 1.2 from Table 690.7 for -7°F

- String calculation sites exist on line for Fronius inverters and SMA Sunny Boy inverters

String Calculation Sites

- Fronius
- Sunny Boy

Array

- Installation containing many strings

Each string could contain 10, 12, 14 ? modules.


What is best racking system for flat roof row home in Philadelphia??

Array

- An array is a string or group of strings.
- The series-connected strings are then connected in parallel to achieve the correct design and desired power levels.
- Two of the earlier sample strings connected together in parallel would produce 10 amps at 350 volts and a total of 3500 Watts
- Modules in array can be connected to individual micro-inverters also and eliminate any string calculations

Array Installation

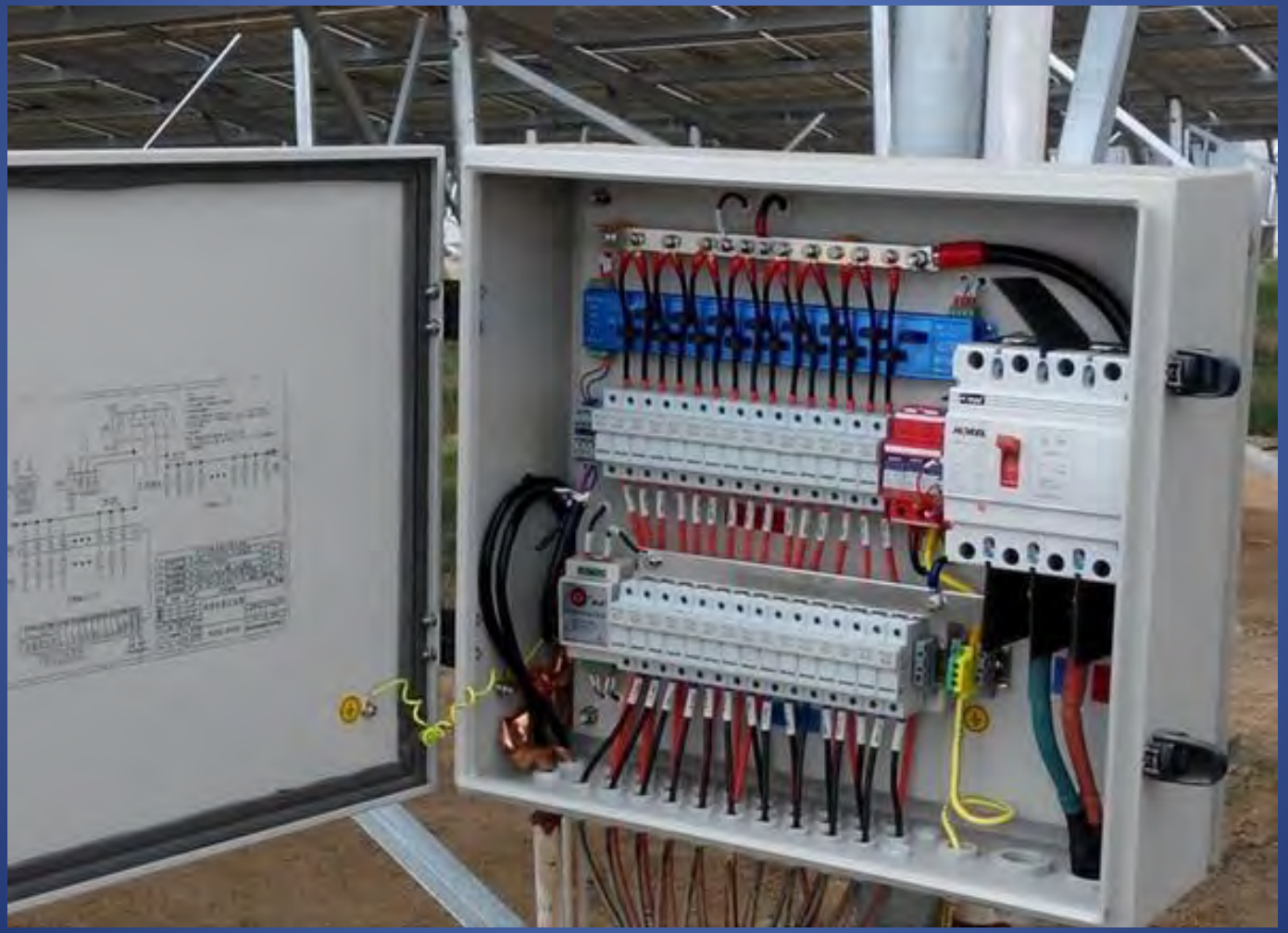
- Standoffs are preferred over Direct Mount
- No trapping of trash or leaves
- No animal nests
- Dwelling unit DOES NOT require a roof-mounted array disconnect switch but …..
- Commercial installations can commonly have most of the components located and installed on the roof
- Array standoffs must be attached to the dwelling unit rafters – not to the roof deck !
- To reduce fire hazard DC arrays must be provided with ground fault protection of the equipment
- Arc-fault protection is required also. Best method to accomplish this??

Combiner

- Fancy junction box that must be “listed” to be used in PV system

How many strings are entered here ??

Combiner for Large Array



Arc-fault Protection

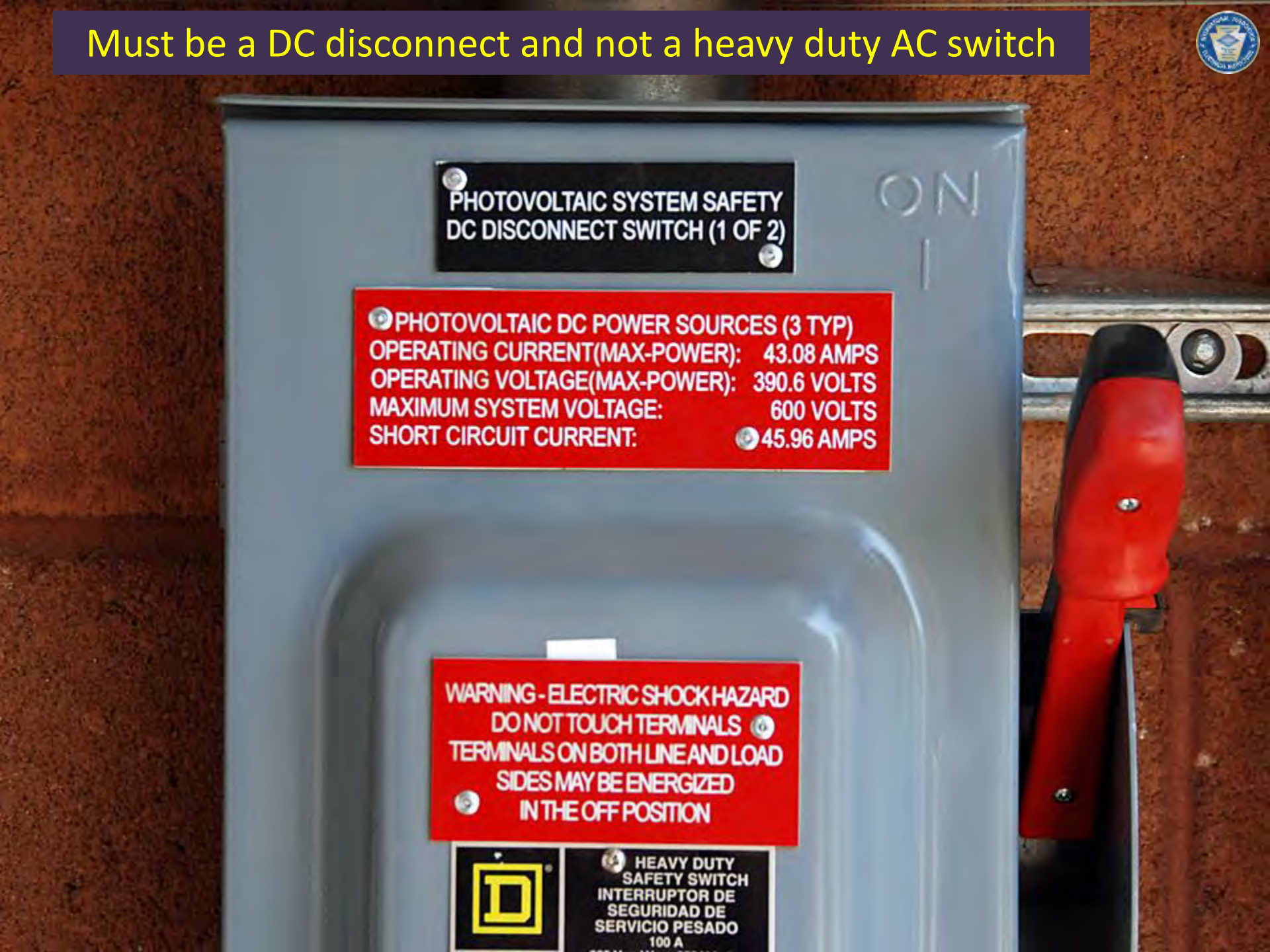
- Arc-fault protection is now required for DC source and DC output circuits

- It was not required prior to the 2014 NEC

DC Disconnect

- Must be listed for DC

Must be a DC disconnect and not a heavy duty AC switch



Inverter

- Changes DC to AC

Solar PV Inverter

- A “central inverter” can handle many strings
- Individual Enphase “micro inverters” can handle one or two modules
- The Andalay “AC” module has Enphase micro inverter permanently attached to the module
- Andalay is incorporated in the state of Delaware was bought out by Westinghouse
- DC PV to DC micro grid uses no inverter at all
- UL Standard 1741 requires that the inverter shuts itself down upon loss of utility electric

Fronius Residential Model Inverter

- 5 kW Fronius SB5000 would handle approximately twenty modules

Inverters for Large Array

Solar PV AC Disconnect

- Ranges from a two pole circuit breaker on up to high amperage and high voltage disconnect switches
- Does not have to be a solar PV listed AC disconnect – just a general use listed AC disconnect
- Can be located indoors or outdoors as required by the utility and the National Electrical Code

Utility Disconnect Switch

- Utility may require an outdoor location for the solar PV disconnect even though the main service disconnect is located indoors
- It is needed for the utility employees use
- Note; the solar PV disconnect switch no matter where it is located is not considered a service disconnect by the NEC

Rapid Shutdown

- Required by the new 2014 NEC Section 690.12 which specified that rapid shutdown equipment be listed and identified
- Any conductors that extend into a building more than 5 feet or extend more than 10 feet from an array
- Limits are not more than 30 volts and 240 volt-amps within 10 seconds

PV Rapid Shutdown

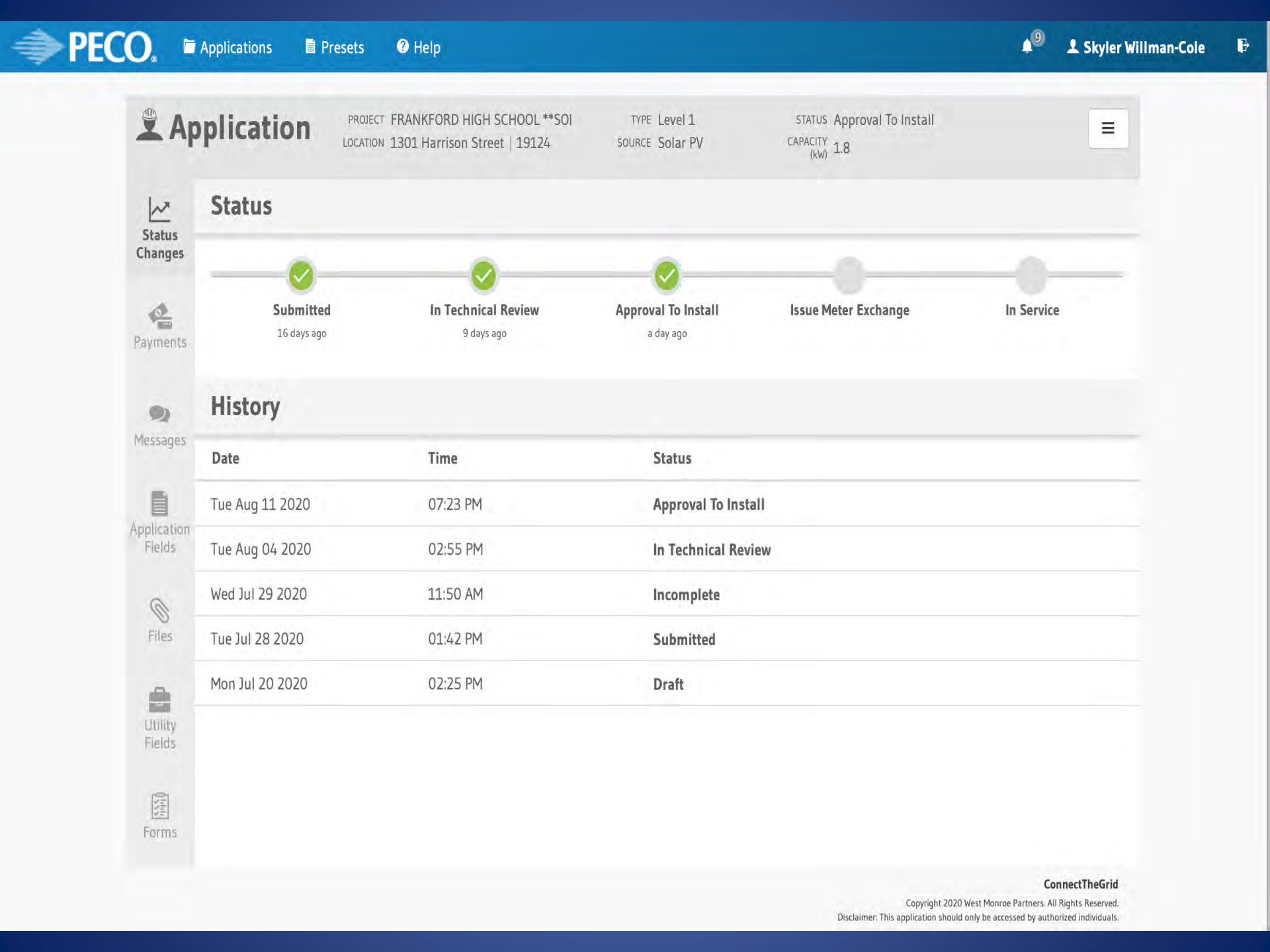
Rapid Shutdown cont.

- Requirement changed in the 2017 NEC to distance of more than 3’ inside of building, 30 volts max and 30 seconds time limit.
- NEC 690.12, 690.56(C)(1) and (C)(3).

https://link.nfpa.org/publications/70/2017/chapters/6/articles/690

Tie-in to Electric Utility

- PECO, PPL, Allegheny Power & Light, Delmarva, PSE&G and JCP&L all have different rules
- Absolute first step for any installation is to get the blessing of the electric utility before proceeding


PECO
Applications
Presets
Help
9
Skyler Willman-Cole
Application
PROJECT FRANKFORD HIGH SCHOOL **SOI
LOCATION 1301 Harrison Street | 19124
TYPE Level 1
SOURCE Solar PV
STATUS Approval To Install
CAPACITY (kW) 1.8
Status Changes
Payments
Messages
Application Fields
Files
Utility Fields
Forms
Status
Submitted
16 days ago
In Technical Review
9 days ago
Approval To Install
a day ago
Issue Meter Exchange
In Service
History
Date
Time
Status
Tue Aug 11 2020
07:23 PM
Approval To Install
Tue Aug 04 2020
02:55 PM
In Technical Review
Wed Jul 29 2020
11:50 AM
Incomplete
Tue Jul 28 2020
01:42 PM
Submitted
Mon Jul 20 2020
02:25 PM
Draft
ConnectTheGrid
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Load Side Tie-in

- Back fed two-pole circuit breaker

Back Fed Circuit Breaker

- NEC Section 690.10(E)

- Permissible to back feed 99% of common circuit breakers but if breaker should happen to be labelled “LINE” and “LOAD” back feed configuration is not allowed

Connecting to the Grid

- There are generally only three ways to connect to the grid;
  - Load side (first preference for residential)
  - Line side (second preference for residential and small commercial)
  - Supply side (whole new set of service conductors with a separate electric meter)

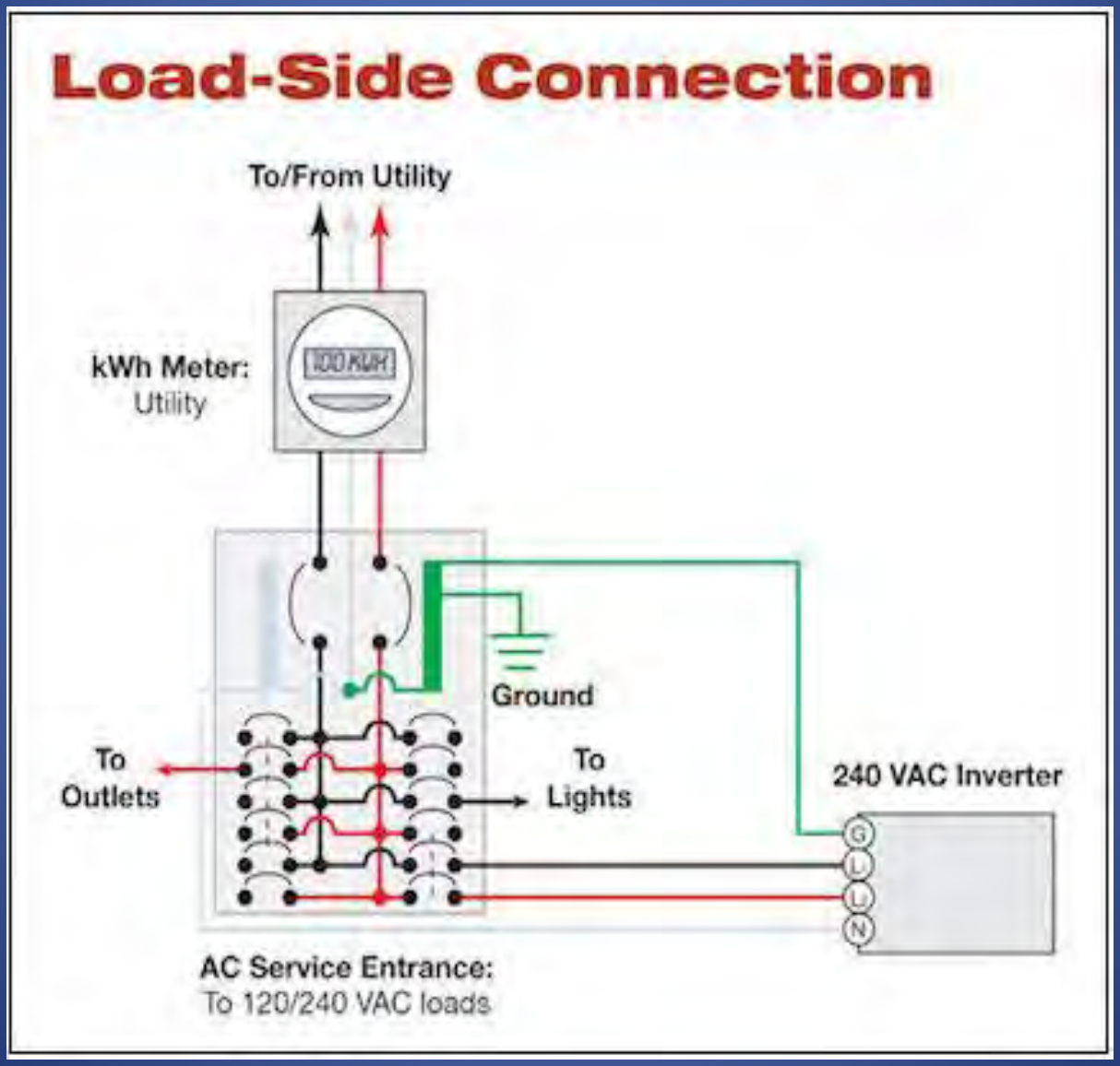
Load Side Connection to Grid

- Can simply back feed a circuit breaker in the existing circuit breaker panel
- The NEC Section 705.12(D)(2)(3)(b) governs the limits of back feed
- Basic calculation is 120% of the bus bar rating is the limit of the sum of the main breaker rating plus the max size back fed breaker allowed

Load Side Tie-in

- When the power finally reaches the circuit breaker panel, simply connect it to a two-pole back-fed circuit breaker
- The circuit breaker must allow back-feed and all circuit breakers do allow this ***unless*** they are marked “Line” & “Load”
- Normally the two-pole circuit breaker is required to be installed at the opposite end of the bus bars from the input end of a main lug panel or main circuit breaker panel (if not, cannot take advantage of the 120% rule)
- Warning label next to circuit breaker must say “Do not relocate” See 705.12(D)(2)(3)(b)

Load Side Tie-in



Load Side Back Fed Breaker Max Value

Bus bar	120%	Total	Main OCPD	Back feed max
100 A	x 1.2	= 120 A	-100 A	20 A
125 A	x 1.2	= 150 A	-100 A	50 A
200 A	x 1.2	= 240 A	-200 A	40 A
225 A	x 1.2	= 270 A	-200 A	70 A

Note: Reducing the size of the main OCPD in this case will allow installer to increase the amount of the PV back fed amps. Is this action NEC code compliant?

Line Side Tie-in

- Connection would be made somewhere between the main circuit breaker in the main panel and the utility meter

- Limit of back feed amperage value is the rating of the service (conductors)

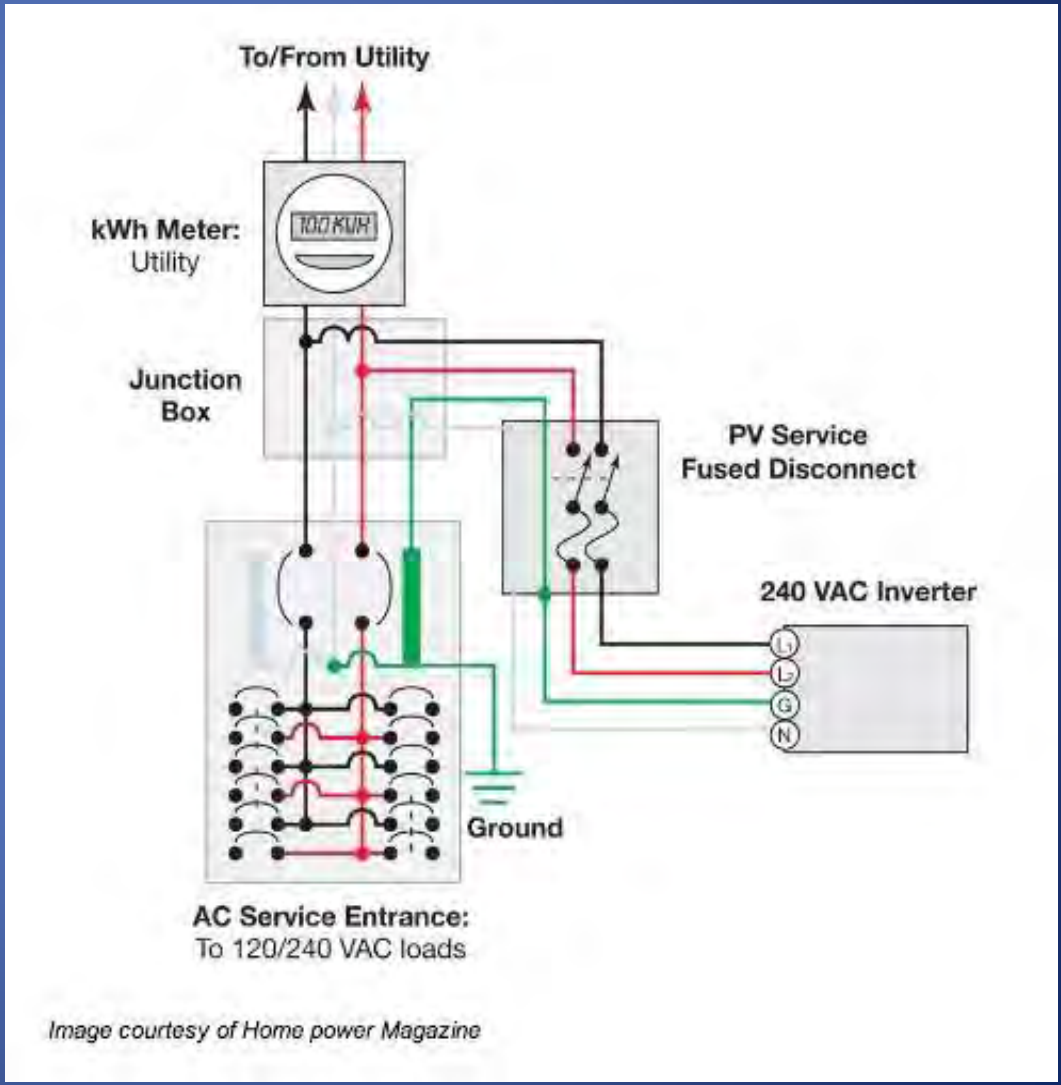
Line Side Tie-in

In the circuit breaker panel if room allows

In a junction box or trough installed between the main circuit breaker panel and the meter socket

In the meter socket itself if manufacturer has lugs that will accommodate

Milbank offers piggy back lugs



Line Side Tie-in

- K-taps are insulation piercing connectors
- Cannot take up more than 75% of cross section of gutter space

KUP-L-TAP

Line Side Tie in NEC Section 705.12(A)

Conductor AWG	Ampere Rating	Max OCPD Breakers or Fuses
2 CU	115 A	100 A + 15 A PV
4/0 CU	230 A	200 A + 30 A PV

Note: Reducing the size of the main OCPD in this case will allow installer to increase the amount of the PV back fed amps

Supply Side Tie-in

- If the size of the array and the amount of current delivered is too large to back feed to the circuit breaker panel and too much for the electric service cable to handle a second set of service conductors and separate electric metering must be installed
- This size of PV array generally requires a PPA (Power Purchase Agreement) between the supplier and the electric utility

Supply Side Tie-in

- This type of connection would be required whenever the system load side back-fed circuit breaker or line side service conductor connection method exceeds the allowable limit.
- Allowable limit is 120% of whatever is feeding or supplying the bus bars of the panel per NEC 705.12 .
- For example: 120% of a 200 amp MCB is 240 amps. Largest back-fed circuit breaker allowed would then be a 40 amp breaker.
- Largest allowed for a 225 amp rated bus bar would be 70 amp breaker (or one 30 amp two-pole and one 40 amp two-pole e.g.)
- Which is it? 200 A or 225 A?

Labeling

- See Handout based on 2017 NEC
- Different labels and information are required for different components.
- Easy to miss labeling either missing or incorrect.

Installation Examples

Concrete vs ground screws. Tilt? Spacing.

Ground Screw vs. Concrete Base

Ground Mount Using Ground Screws


Thin-film product

Lay modules flat??

Commercial Install Ground-Mount

Ballasted System

Ballasted System

Pavilion with module seals

Residential examples

Alternate Install examples

Building-Integrated PV Systems

Sharp Electronics Corp.

SHINGLES

WINDOWS

DOE/NREL, Lawrence Berkeley Lab

SKYLIGHTS

DOE/NREL, University of Texas Health Science Center at Houston

AWNINGS

New Jersey project

The New SUNMODO

SunTurf Elevated Flat Roof

The New SUNMODO

SunTurf Elevated Flat Roof

Key Features

1) **Span over roof obstructions:**
   - Install on roofs you previously said no to
   - Increase ROI by maximizing number of panels on the roof

2) **Versatile and flexible layout options:**
   - Tilt angle from 5° to 50°
   - Configured for 2P, 3L, and 4L standard layouts or custom designed to your needs
   - Up to 8' of roof clearance
   - Capable of low tilt monolithic layout to cover whole roof

3) **Layout and stamped drawings available**

Show more value to customers on flat roof projects

Other Solar Energy Usage Examples


Build Facing South Forevermore?
PV and H_2O heat for each condo

1.3 Installation Methods

- Regardless of the type of structure supporting the array whether it is a:
  1. Roof
  2. Wall
  3. Foundation
  4. Ground

  The strength and rigidity of the support structure must be evaluated
- This is especially important when installing PV as a retrofit since the building was not originally designed to carry such a load

Ground-mounted arrays

- What is soil condition
- What is water table – standing water/flood plane
- Shading concerns again
- Down slope when facing south is better than down slope facing north.
- Array rows can be installed closer together and more of them on a south down slope than on level ground.

On Downhill Slope Facing South

On Downhill North Facing

Requires large spaces between rows to avoid major shading issues

Data monitoring once the system is installed

- As simple as a second KWH meter or
- As sophisticated as a data monitoring website.

Power and Energy

Day | Week | Month | Billing Cycle | Year

09/23/2020

System Production: **9.36 kWh**

95% | 5%

Self-consumption: 8.87 kWh

Export: 0.49 kWh

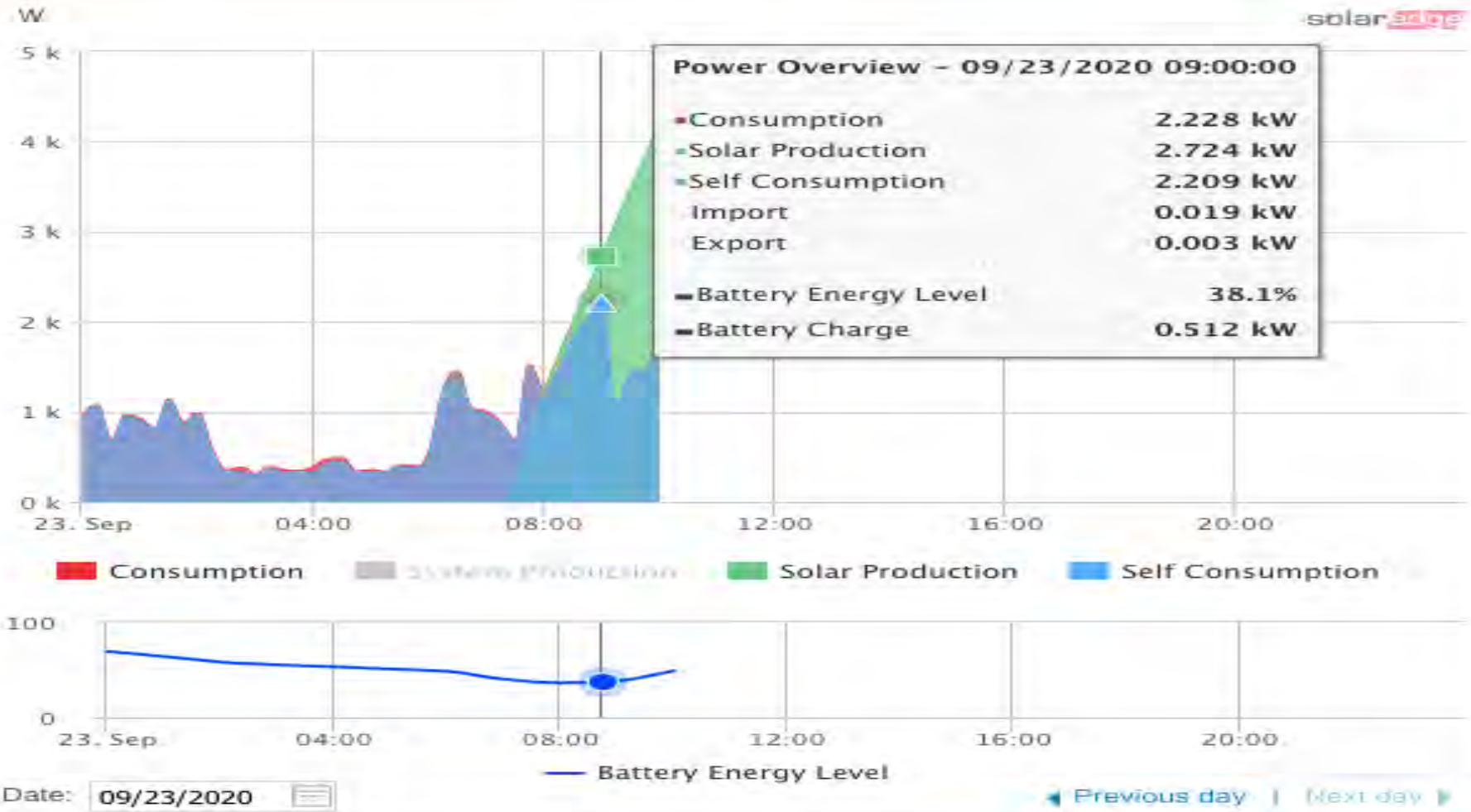
Consumption: **9.61 kWh**

92% | 8%

Self-consumption: 8.87 kWh

└ 8.33 kWh from batteries (93.9%)

Import: 0.74 kWh



Date: 09/23/2020

Previous day | Next day

Complying with the NEC and Building Codes

2018 International Residential Code

- Section 324 contains requirements for PV systems.
- New to 2018 IRC is 324.6 which requires access pathways. This is extremely important for firefighting efforts.
- https://codes.iccsafe.org/content/IRC2018P7/chapter-3-building-planning#IRC2018P7_Pt03_Ch03_SecR324.3

Residential Roof Attachment issues – Lags

- Usually use lag screws/screw threads
- Drive lags into rafters, not plywood decking
- Pre-drill the pilot holes for lag screws
- After shingles, decking, hardware etc., drive at least 2 ½ inches into rafter
- Some arrays (ballasted) do not attach at all to roof, only sitting on flat roof and held down with weights (ballasted system for commercial buildings)

Allowable Withdrawal Loads*

Lag screw Diameter$_{\dagger}$	Wood type		
	Southern Yellow Pine	White Spruce	Douglas Fir
1/4	281	192	167
5/16	332	227	198
3/8	381	260	226
7/16	428	292	254
1/2	473	323	281

- In lb/inch
- † in inches

Lag screw length calculation:

- Array is 200 sq. ft.
- Engineering lifting wind load is 45 PSF
- 24 brackets are planned
- Roof deck/surface is 1” thick
- Rafters are southern yellow pine
- Lag screw is 5/16” diameter

What is total lifting force:

- 200 sq. ft. x 45 PSF = 9000 lb

therefore…9000 lb ÷ 24 brackets = 375 lb per point..

What is withdrawal resistance of the 5/16” lag screw?

- 332 lb/inch

What is thread penetration depth required?

- 375 lb ÷ 332 lb/inches = 1.13”

Therefore….1” thick roof + 1.13” holding = 2.13” long

- Next common size?

2 ½” or 3” long…

Approved Installer

- This is a requirement of the NEC
- Must meet NABCEP or IREC standards
- North American Board of Certified Electrical Professionals
- Interstate Renewable Energy Council
- NABCEP includes two exams
- IREC-approved training is available
- NEC only requires that PV installations be made by “Qualified Persons”

Installation of Solar PV Systems

- Section 690.4(C) in the NEC requires that the PV be installed by a “qualified person”
- PV conductors shall not be mixed in the same raceway or cable as non-PV conductors
- PV source circuits must be identified at all points of termination, connection and splices
- Ground fault protection provided by 1 amp fuse
- Arc-Fault protection now required per 690.11 for DC PV output circuits

Inspection of Installs

- Before starting the PV project the contractor:

- Must be registered and or licensed with the State. In Pennsylvania the contractor who works on dwelling units must be registered with the state Attorney General office. The contractor will be assigned an HIC (home improvement contractor) registration number. It is not a license

- Must file a Service & Meter (S&M) form with the electric utility and received approval for the planned installation

Inspections of Installs con’t

- Must have pulled a permit for the work
- This can include building and electrical permits or just an electrical permit depending on the municipality
- May have to receive approval from state agencies (forms must be submitted) if interested in getting rebates that may be available

Array Installation

- Standoffs are preferred over direct mount
- Should be no trapping of trash or leaves
- Want no animal nests that cannot be cleared out
- Dwelling unit DOES NOT require a roof-mounted array disconnect switch but some installers put one on roof for every project anyway for convenience
- Array standoffs must be attached to the dwelling unit rafters – not to the roof deck !
- Commercial installations can commonly have most of the components located and installed on the roof

Direct mount

Standoff Mounts

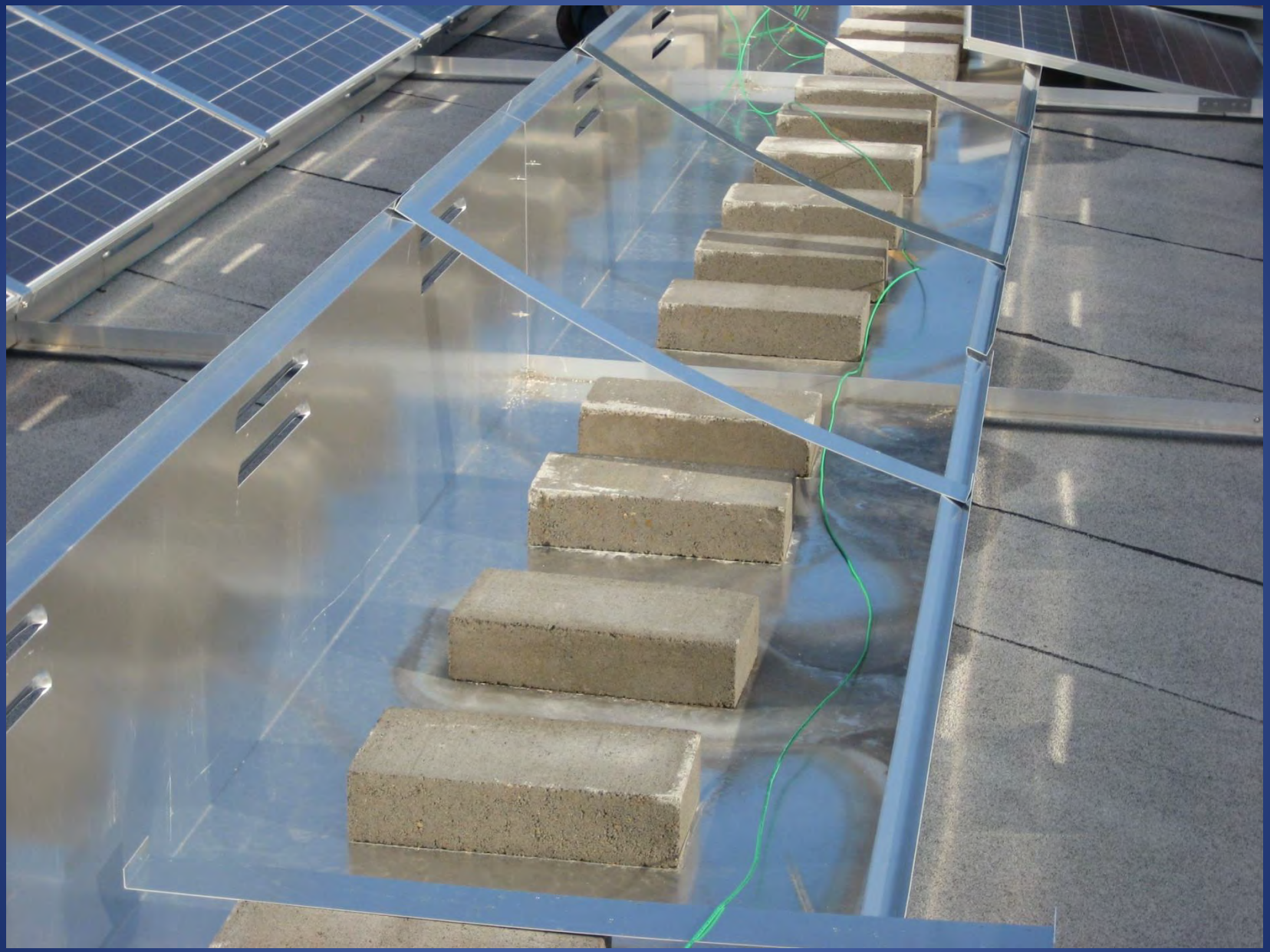
Commercial Arrays

- Usually use a manufactured “ballasted” frame support system
- Ballasted system uses weight to hold the array in place.
- No roof penetration
- Keep all conductors tied up and secured under the array with ty-wraps or other approved means
- Do not allow conductors to lay on roof


New Jersey Project

New Jersey Project


Glenside PA Project




Maple Shade NJ

Indoor material used outdoor

Ampacity Adjustment

- Twenty 10 AWG PV conductors in previous slide are rated USE-2
- Table 310.15(B)(16) 3rd column for copper says 40 amps is max the conductor can carry
- Table 310.15(B)(3)(a) reduces the amount by 50% to 20 amps.
- In Table 310.15(B)(3)(c) rooftop temperature adder for ampacity adjustment is moot if XHHW-2 conductors are used.
- Rooftop temperature adder was deleted in 2017 NEC unless conduit lays directly on the roof

Sizing the DC Conductors Overcurrent Protection

- Multiply 125% of the maximum current already calculated in the previous steps.
- Shortcut is to multiply the short circuit current by 1.56 (125% x 125% = 1.56) per NEC 690.8(A) and (B)
- Module rated 7.5 amps x 1.56 = 11.7 amps
- Next standard size up?
- Where is the DC overcurrent device situated?

Module Connectors

- Cannot just wire nut the module tails together.
- Connectors must require a “tool” to disconnect them per 690.33(C)

Fine Stranded Cables Generally

- Fine stranded conductors cannot be terminated into a mechanical lug.
- They must terminate into a “listed” connector like a crimp lug 690.31(H) then 110.14

DC Disconnect

- Must be a listed DC disconnect
- Does not have to be “service rated”
- What qualifies the disconnect as “service rated” equipment?
- Can be fused or un-fused ***but***
- Fuses are required to protect the “string”
- Must have DC rated fuses
- There are fuses that have an AC/DC label
- Must be labeled per 690.13(B)

DC Disconnect cont.

- Disconnect location
  - Outdoor per electric utility requirement
  - Indoor just before the central inverter
  - Indoor in the central inverter itself
  - Both locations exterior and interior


SOLAR DC DISCONNECT
WARNING!
ELECTRIC SHOCK HAZARD. DO NOT TOUCH TERMINALS!
Terminals on BOTH line and load side WILL BE ENERGIZED
in the open position ANYTIME the solar panels are exposed to the sun!
HEAVY DUTY
SAFETY SWITCH
INTERRUPTOR DE

This style DC disconnect allows for replacement of central inverter without disconnecting any power wiring

Inverter

- Changes the DC to AC
- Matches the utility amplitude, frequency and phase or it will not connect
- Must provide ground fault protection for equipment – not personnel GFPE vs GFCI
- Must meet UL 1741 requirements which means among other things, no “islanding”
- If utility line is lost on a grid-connected system the inverter must turn itself off

Inverter cont.

- Reconnection attempts will be made every five minutes.
- What if an optional standby generator starts up when utility goes down?

AC Disconnect

- Required for the inverter output
- Does not have to be “service rated”
- Must be grouped with the main service disconnect(s)
- Can be the two-pole back-fed PV circuit breaker ***if*** the inverter is located near to the main circuit breaker panel
- If the inverter is located remotely in the basement and the main circuit breaker panel is in the garage, an AC disconnect would be required in the basement in addition to the two-pole circuit breaker that is located in the main panel.

AC Disconnect Label

WARNING

ELECTRIC SHOCK HAZARD

DO NOT TOUCH TERMINALS.

TERMINALS ON BOTH THE LINE AND LOAD SIDES MAY BE ENERGIZED IN THE OPEN POSITION.

Per NEC 690.17(E)

Utility Disconnect

- Required by the electric utility and handy way for the firemen to disconnect the Solar PV system from the house AC service also.

- Approval for location of disconnect must come from electric utility company

PECO Required Two Meter System in PA. NJ Uses One Smart Meter

PECO recently developed a “Yellow Book” for the interconnection of alternate sources. Only a single meter required now for 100 and 200 amp services

Attachment issues – lag bolts

- Always use stainless steel lags
- Use SS to install modules on support rails
- Manufacturer will specify size and type
- Use threaded rod when necessary
- Use lock washers
- Use compatible metals

Miscellaneous Photovoltaic Energy Systems

Inverter Technical Data

- SMA Sunny Boy
- Fronius
- Max Input DC
- Max Output AC
- Temperature concerns
- Shading
- Anti-Islanding

Snow Load Residential A-Frame Roof

- Do we need to address it?
- How does snow help or hurt production?
- How does latitude and building design help or hurt this problem?
- Don’t worry about snow staying on PV array - worry about it sliding off
- Second layer of shingles = 2.4 lbs per sq ft
- 34 lbs of PV per 15 sq ft is easily handled by A-frame roof at 2.3 lbs per sq ft

Avoiding Common Code Violations

Inspections

Cannot be made from the ground for roof-mounts. You must get up on the roof to inspect the solar PV installation.

You Make the Call

- Review and discuss the following photos

Single Module Damaged

Damage cause?

Connectors Damaged

- Cause? Factory or field made connections for final tails to combiner

Junction Box Damage

- Cause?

DC Combiner Damage

- Cause?

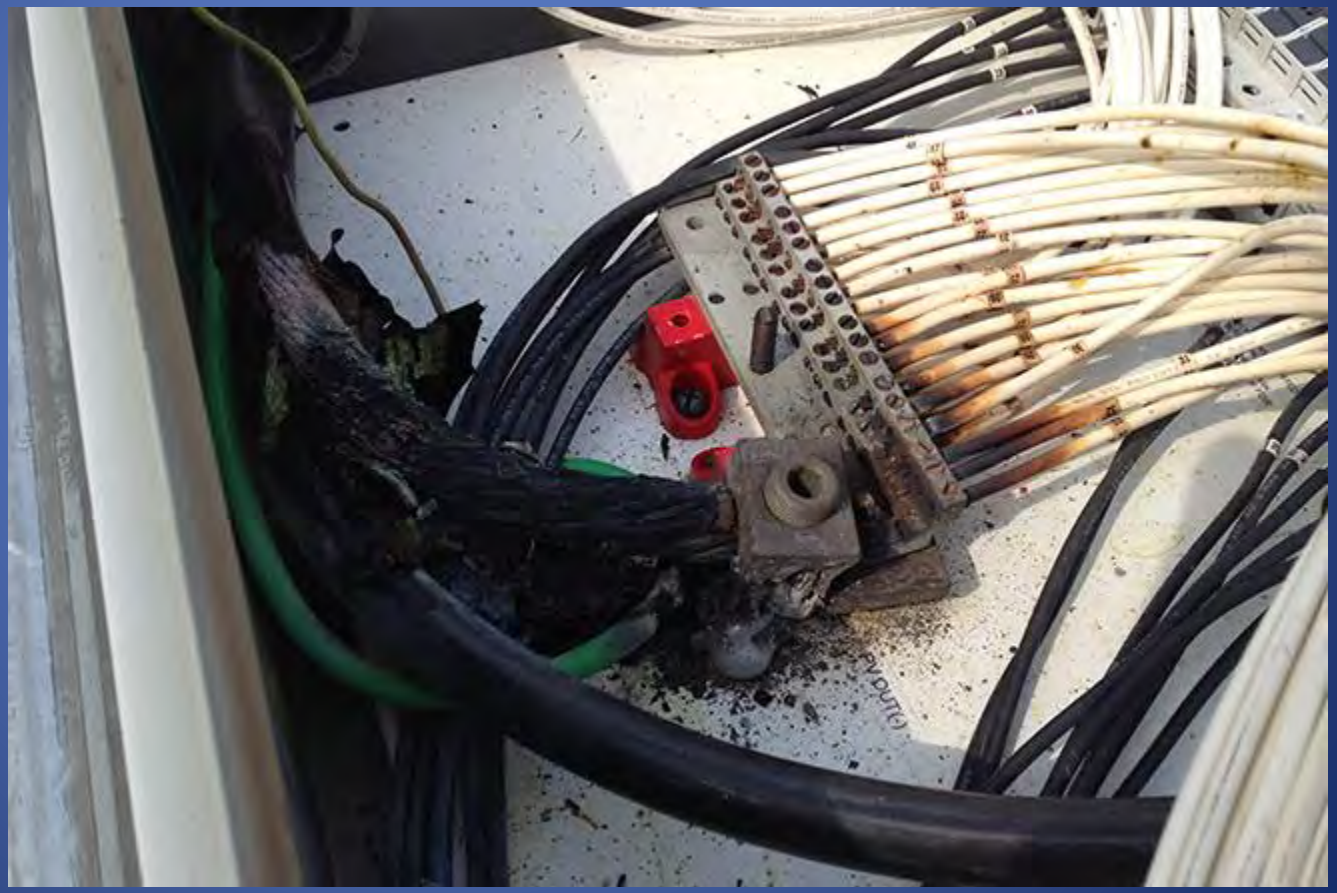


Exhibit A

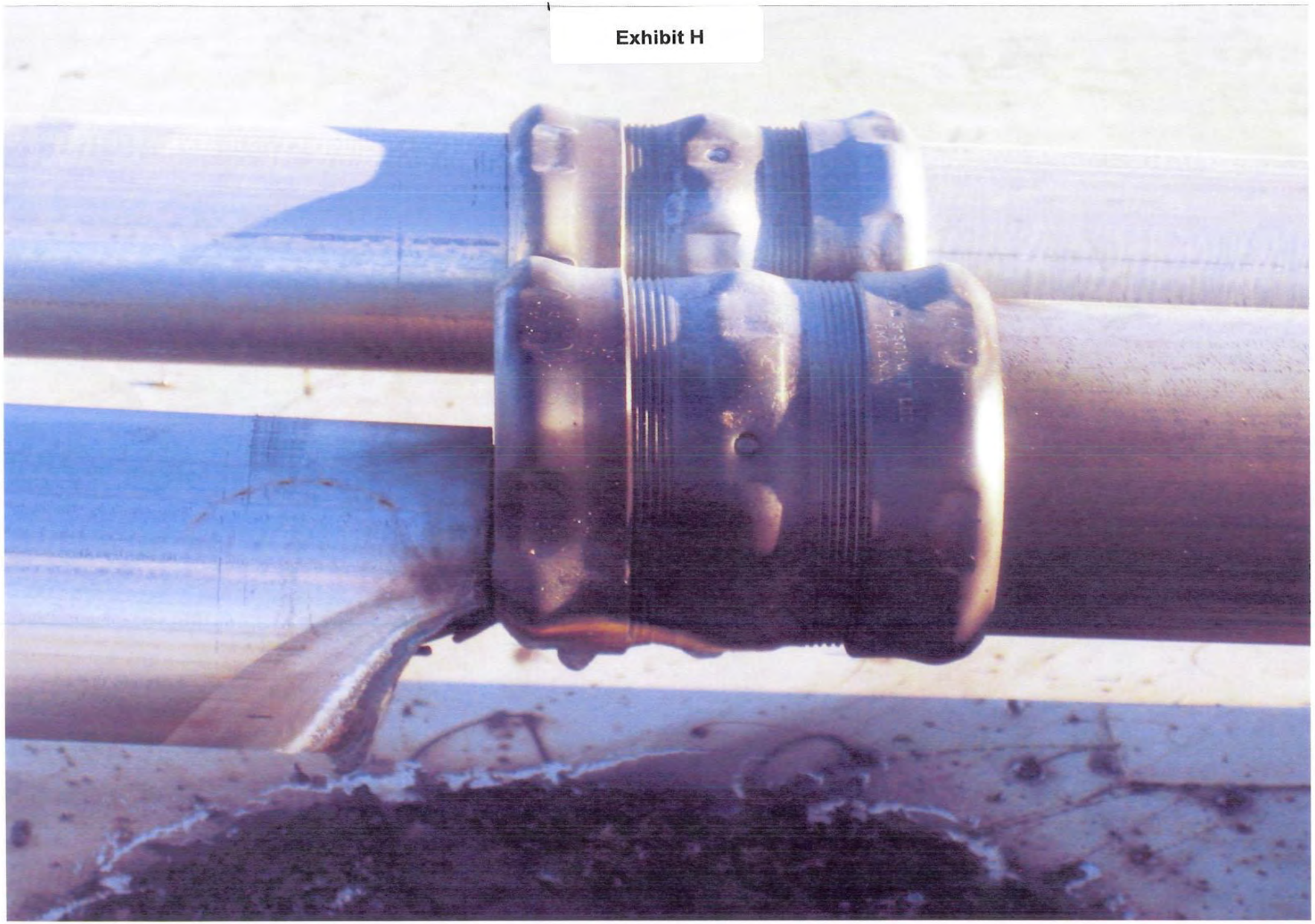
Exhibit D

Exhibit F

Exhibit L

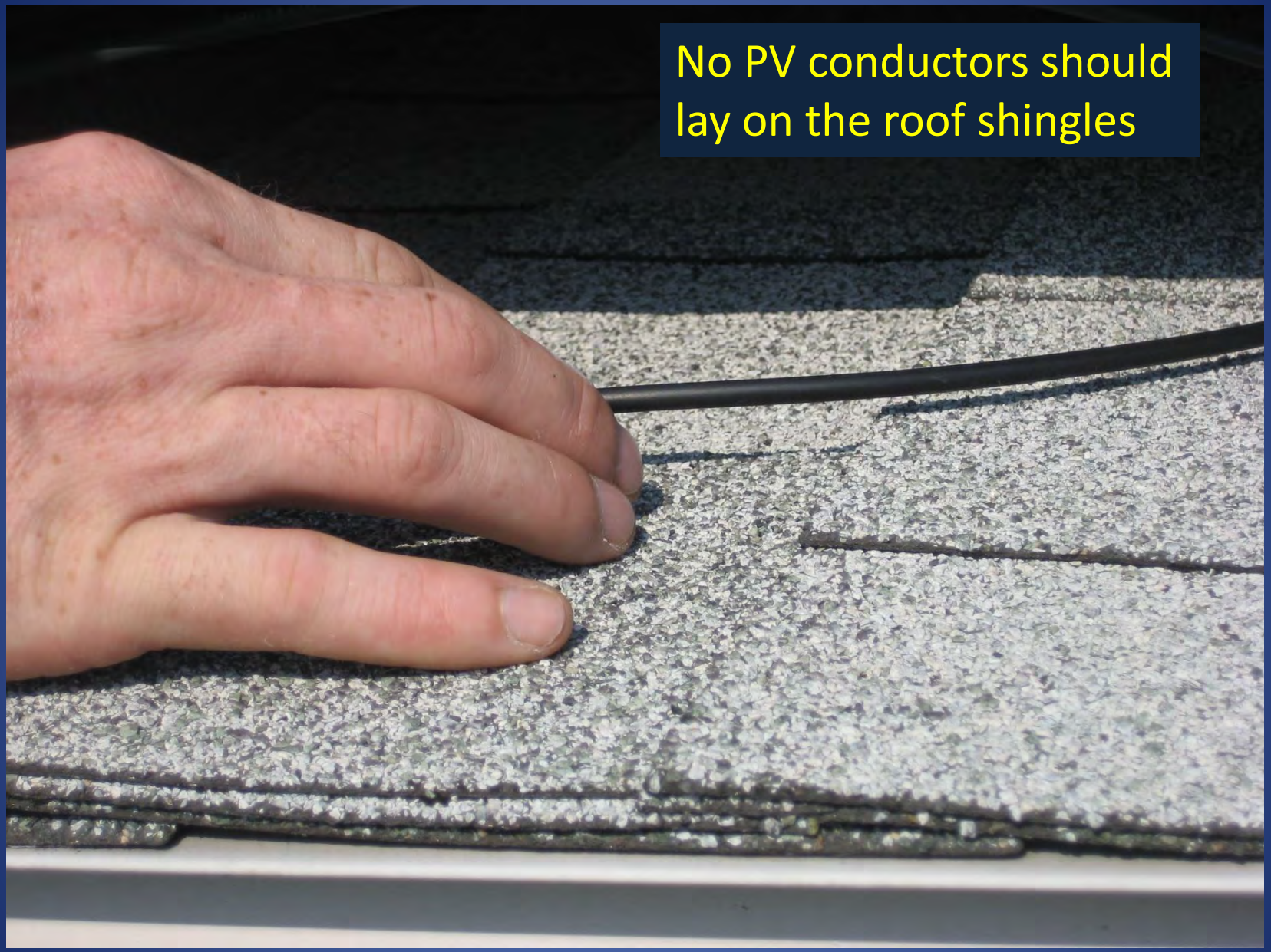
Exhibit G

Exhibit H




Poor workmanship


Correct method of entering
through a roof surface
using a pitch pocket

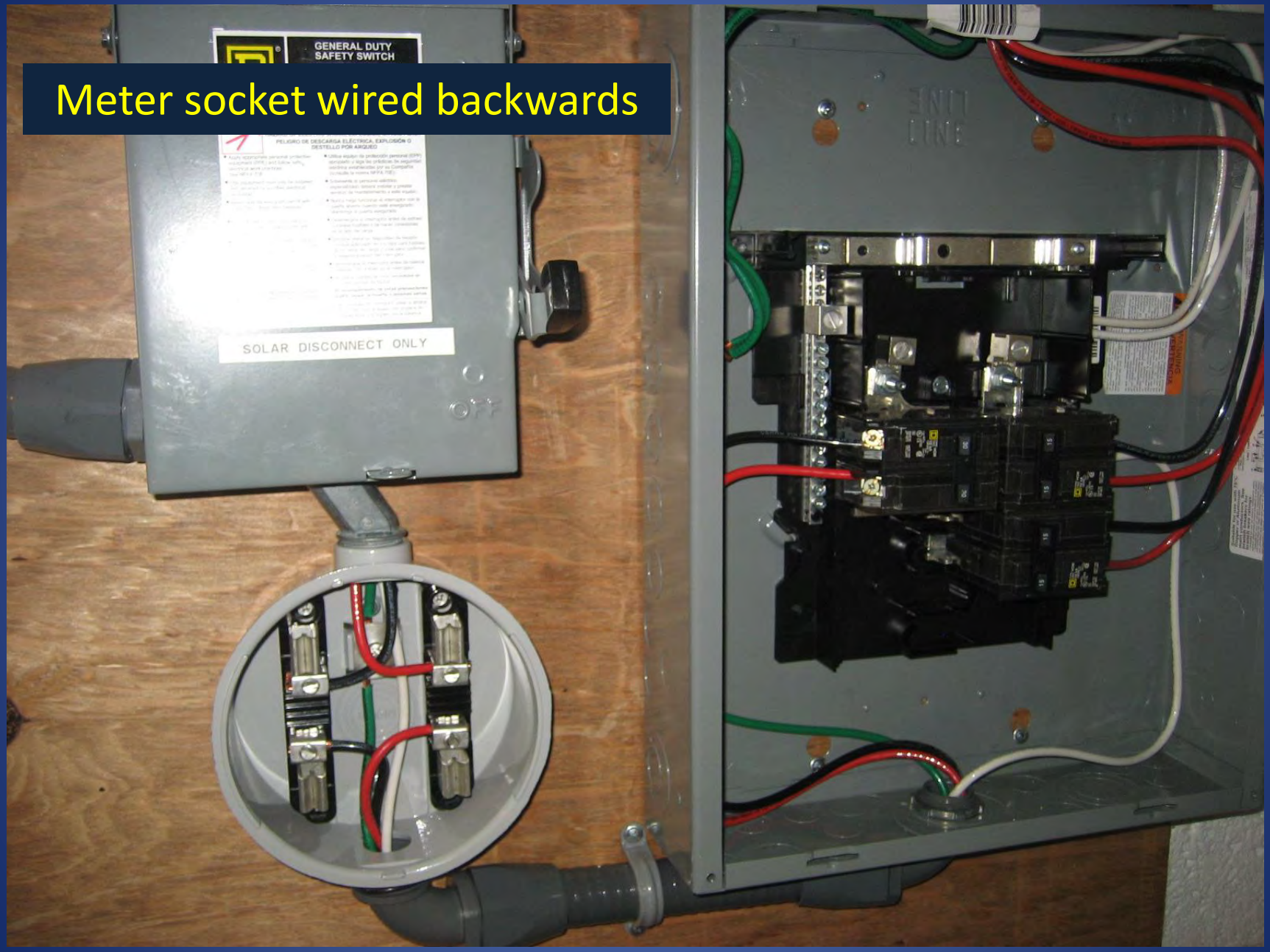

No PV conductors should lay on the roof shingles


PVC expansion sleeves
required in most situations.
Refer to NEC Article

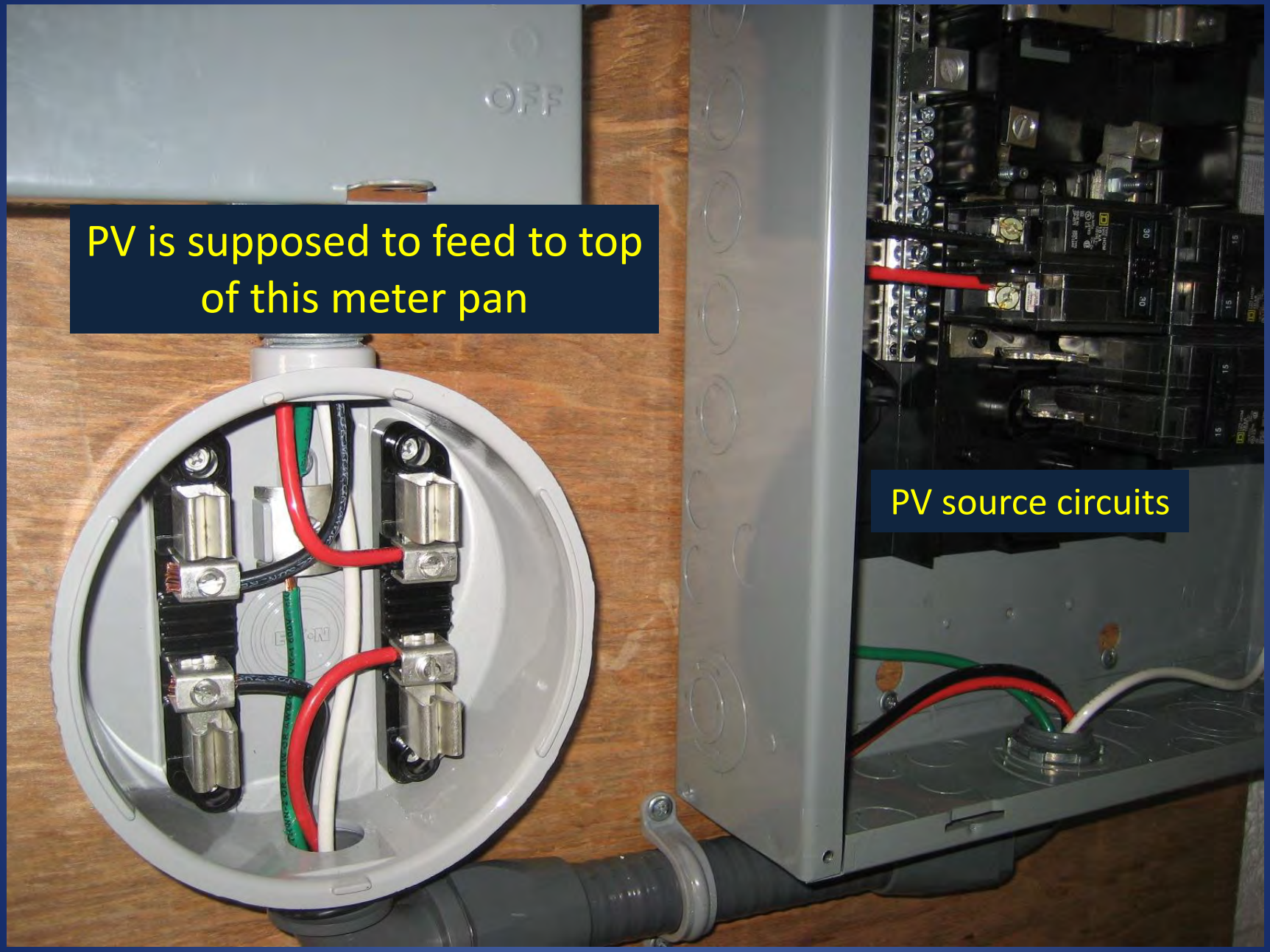

Think ahead before going up on a roof.
What could possibly go wrong?


Liquid-tite conduit does not follow building lines

Upside down PVC expansion fitting



Meter socket wired backwards


PV is supposed to feed to top of this meter pan
PV source circuits


Two problems


PV conductors trained directly on sharp edges
136047-1-MSHA 11/19/08 (B5802)


Trip hazard between rows


CAUTION:SOLAR CIRCUIT
No working clearance here


MILBANK
EATON
No working clearance here at all due to gas meter

Weather station reports temperature, wind speed and direction, amount of sun


Put a lid on it


WARNING!
600 VDC CIRCUIT COMBINER
ELECTRONIC SHOCK HAZARD
DO NOT TOUCH TERMINALS.
TERMINALS ON BOTH LINE AND
LOAD SIDES MAY BE ENERGIZED
DURING DAYLIGHT HOURS!


WARNING
ELECTRICAL SHOCK HAZARD
DO NOT TOUCH TERMINALS
TERMINALS ON BOTH LINE AND
LOAD SIDES MAY BE ENERGIZED
IN THE OPEN POSITION


WARNING!
600 VDC CIRCUIT COMBINER
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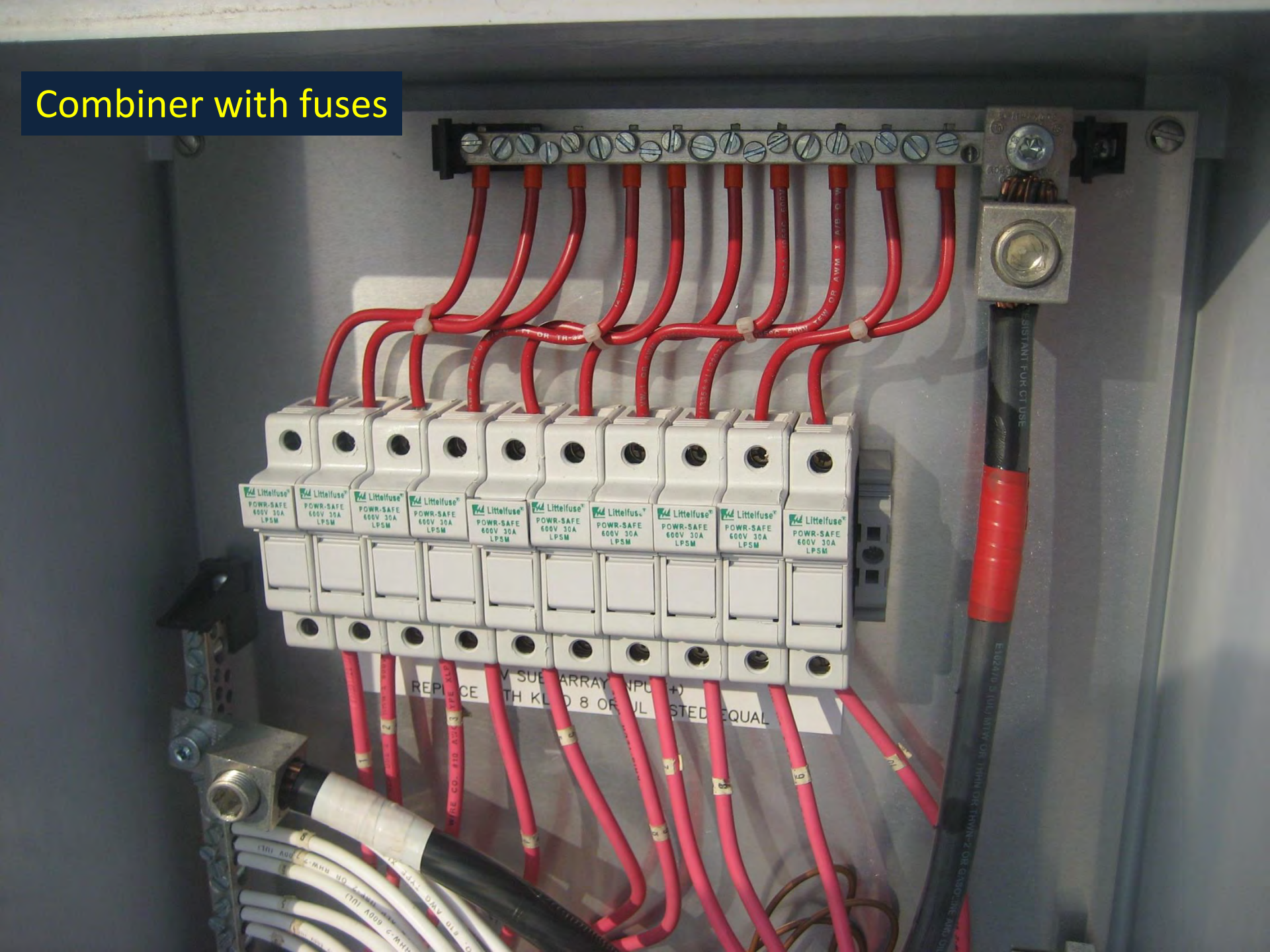
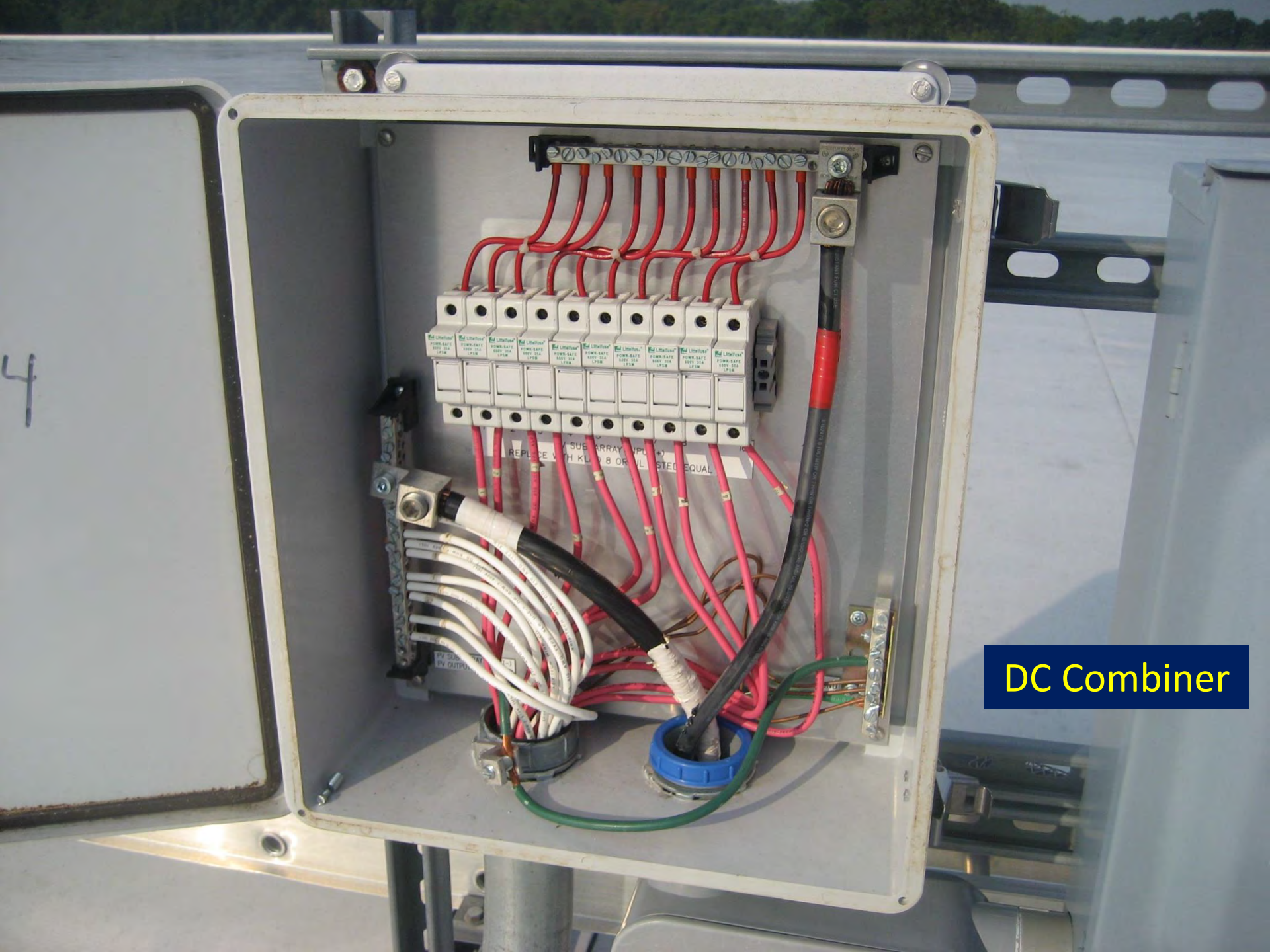
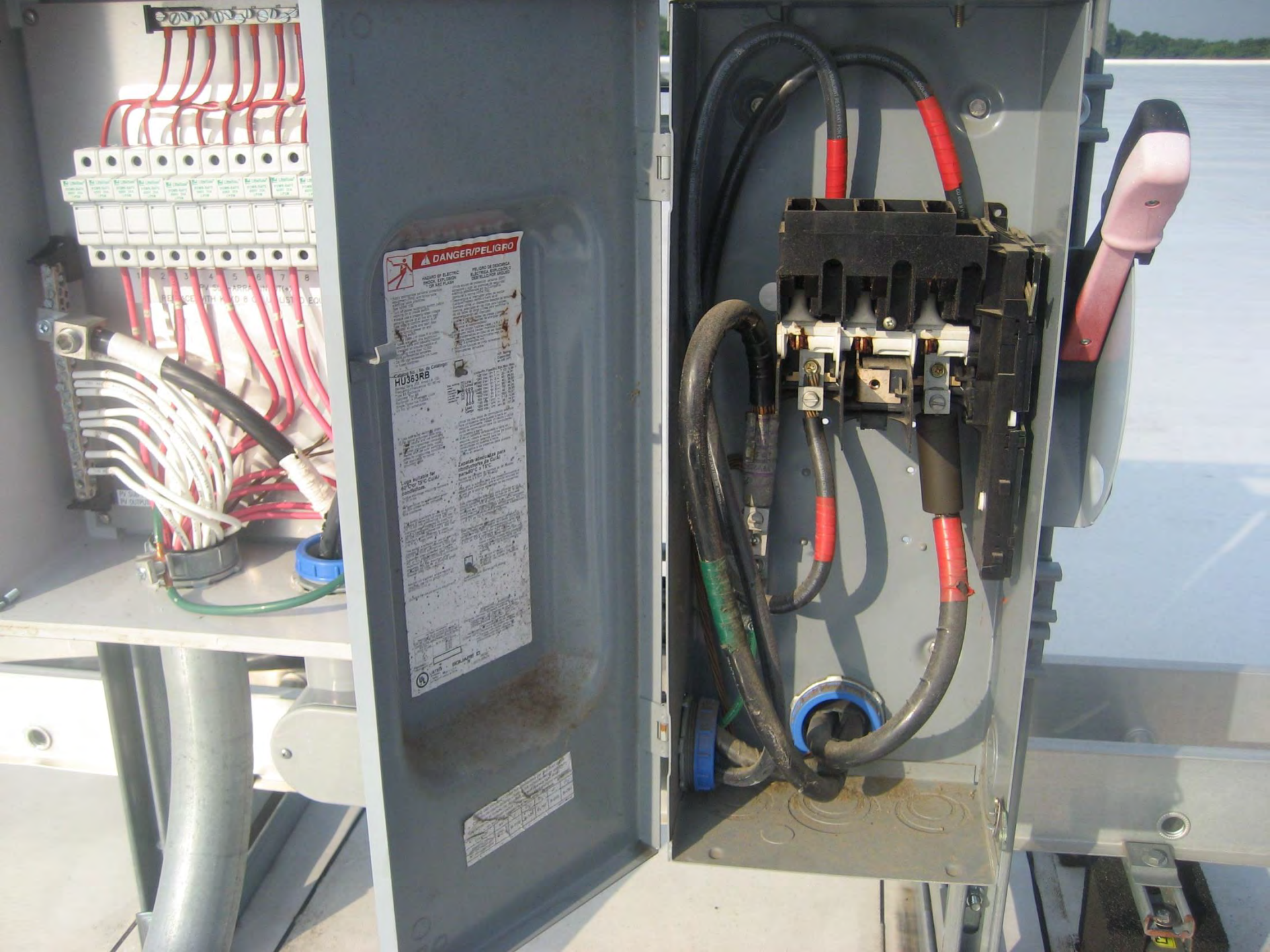
WARNING
ELECTRICAL SHOCK HAZARD
DO NOT TOUCH TERMINALS
TERMINALS ON BOTH LINE AND
LOAD SIDES MAY BE ENERGIZED
IN THE OPEN POSITION

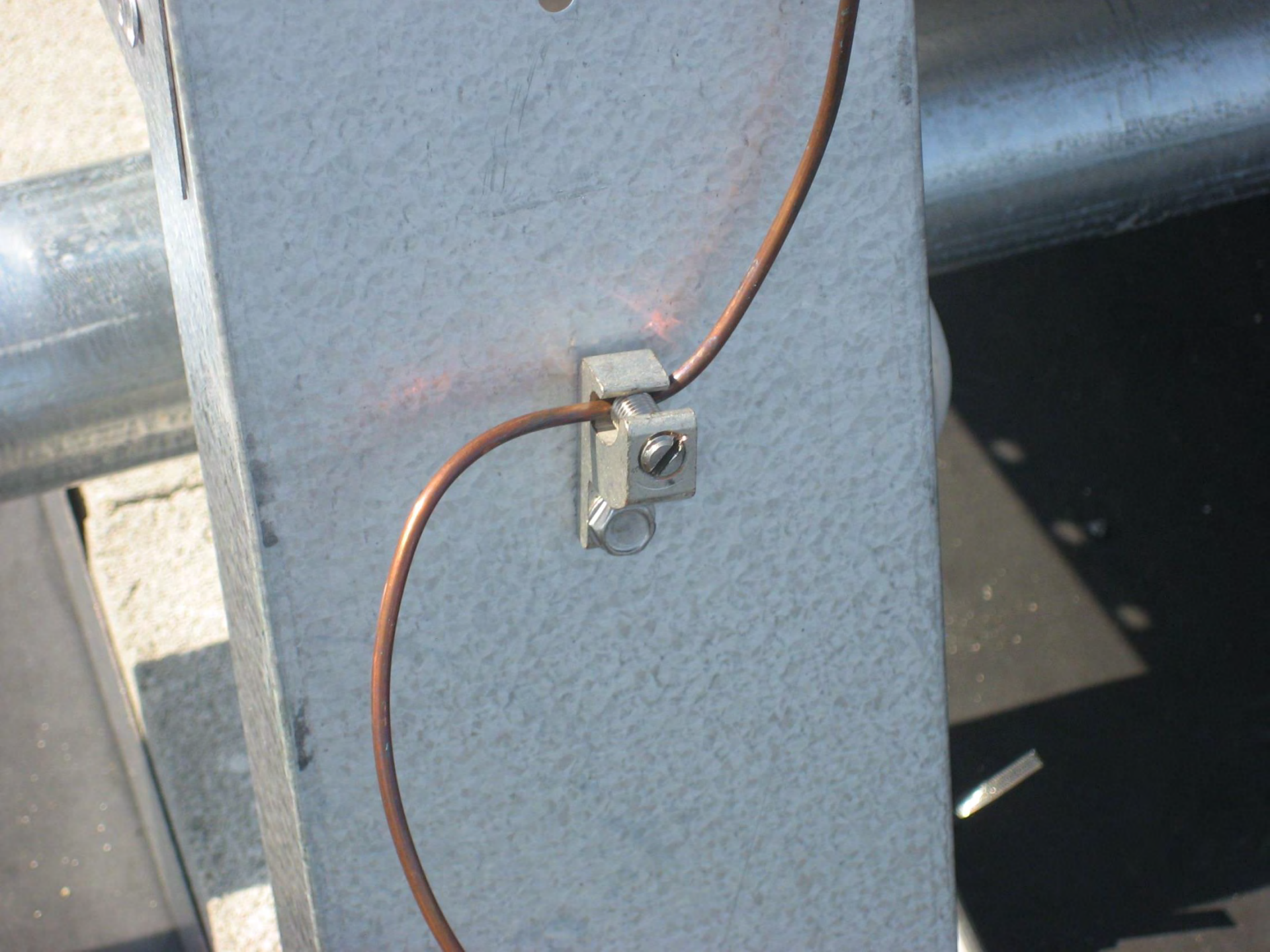
Combiner with fuses




DC Combiner


DANGER/PELIGRO
HU363RB

USE-2 OR RHW-2 600V




600 VOLTS 2008

Other Rules

- Remember that a circuit breaker cannot be continuously loaded to more than 80% of its rating. NEC 210.20(A)
- Continuous means 3 hours or more at full load
- Translation: the most you can back-feed a 40 amp PV circuit breaker since it is a continuous load would be 32 amps

Residential

- Residential debacle of an install

Array mounting systems

- Fixed tilt
- No adjustment without difficulty

Array mounting systems

- Adjustable tilt:
  - flatter in summer,
  - more upright in winter,
  - can also adjust the azimuth angle

Module Mounting Systems

FIXED-TILT MOUNT

ADJUSTABLE-TILT MOUNT

Array mounting systems

- Roof doesn't face south?
- Solutions;
  - Standoff mounts: attach directly to rafters
  - Pole mounts
  - Ground mounts – physical damage, vandalism

Roof Mount Options

- Direct mount
  - Thru-roof and attach to building structure
  - Definitely not recommended

Direct mount


Quick-mount aluminum flashing

Roof Mount Options

- Roof rack mounts
  - Some attached
  - Some ballasted with weights only

Roof Rack Mounts

Roof Mount Options

- Standoff mounts
  - Used for shingled or flat roofs
  - One standoff support per so many feet
  - Can be installed before roof finish
  - Can be installed on existing roof surface

Standoff Mounts

Best approach to sealing a roof

- Use flashings and rubber boots
- That is possible on retrofits
- It is easiest on new roofs

Best approach to sealing

- Offer re-shingling/reroofing to owner as an option
- Re-shingling/reroofing kills many birds with one stone..
  1. No leaks
  2. Ensure location of rafters
  3. Relocate vents, caps, fans, etc.

Accessibility

- Convenient access for:
  1. Installation
  2. Inspection
  3. Maintenance
  4. Material Loading/Storage
- Do not locate components in attics, crawl spaces, or other locations difficult to access if at all possible

Roof – What to do?

- Record condition of surface (metal, flat, shingle)
- Record condition of supports under the roof deck. Joists, rafters and trusses if any.
- Check ceiling finishes inside of building for signs of pre-existing leaks. Take photos before and after
- Consult or partner up with a professional roofer
- How one installer handles it.