1

Doug Smith, MCP/CBO

- Inspector/Plan Reviewer for over 19 years
- 19 ICC certifications
- Certified ICC Master Code Professional and CBO
- Taught electrical, solar PV, and ESS classes for over 13 years
- Performed well over ten-thousand electrical, solar PV, and ESS plan reviews
- Serve on *NEC* CMP 10 representing IAEI
- Currently serve as a Technical Committee (TC) Member for the following UL standards:
  - UL 61730 (previously 1703) – Flat-Plate PV Modules and Panels
  - UL 1741 - Inverters, Converters, Controllers, and Int. equip…
  - UL 2703 – PV Mounting Systems/Clamps/Gnd. Lugs
  - UL 6703 – Connectors for Use in PV Systems
  - UL 9540 - Energy Storage Systems and Equipment

2

Course Objective/Intent

- The objective of this presentation is to explain the core *NEC*/*IRC* requirements that govern solar photovoltaic (PV) systems. This presentation is based on the **2020 *NEC* and 2021 *IRC***.
- The intent of this information is to be used as a guide only. This presentation is not intended to indicate any change in any code or local requirements by inference or omission. All diagrams are for illustration purposes only and actual wiring and installation may vary. This presentation is not intended to indicate if one piece or particular brand of equipment is better than another. Also, efficiency and ideal design considerations are not addressed herein. All applicable codes, standards, and manufacturer requirements must always be followed when designing, installing, and inspecting any electrical system, including solar PV and/or battery/energy storage systems.

3

Outline

1. **PV Modules and Module Interconnections**
2. **Inverters**
3. **Rapid Shutdown**
4. **Micro Inverters VS String Inverters**
5. ***IRC* Roof Access Requirements**
6. **Wiring Methods**
7. **Grounding and Bonding**
8. **Point of Interconnection Requirements**
9. **Example Plan Reviews of PV Systems**

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PV Modules (solar panels)

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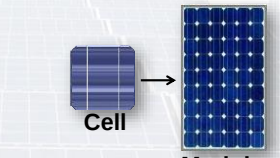
PV Modules

- PV cells make up a PV module (solar panel).
- All modules together in a system make up the array.



Module (solar panel)

Array

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Module Listing

- All photovoltaic modules must be listed as meeting UL UL 61730 (1703).
- *NEC* 690.4(B)

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PV Module Interconnections

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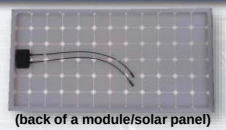
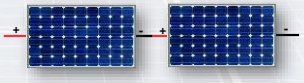
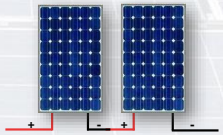
Concept of Series-Connections

- A circuit with multiple modules that are connected in series is referred to by the *NEC* as a "PV Source Circuit," but is often called a string of modules by the PV industry (PV string circuit).


(back of a module/solar panel)


Or


Series connected modules

Note: these diagrams are very basic in order to explain the concept of solar panels connected in series. Most modern-day systems are required to also include rapid shutdown components (such components are not shown here).

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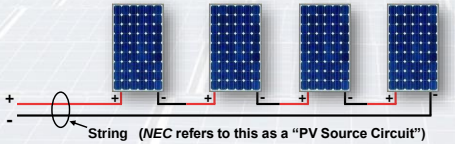
Series vs. Parallel

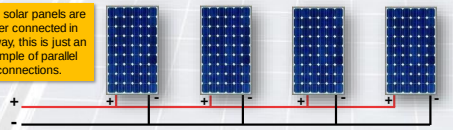
Series connected modules (solar panels):

Volts from each module add together but amps stay the same:


String (*NEC* refers to this as a "PV Source Circuit")

Parallel connected modules:

Amps from each module add together but voltage stays the same.



Note: solar panels are never connected in this way, this is just an example of parallel connections.

Note: these diagrams are very basic in order to explain the concept of series versus parallel connections. Most modern-day systems are required to also include rapid shutdown components (such components are not shown here).

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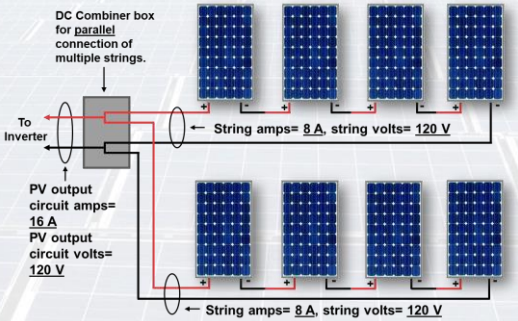
Example of how series and parallel connections affect a system

If each module (solar panel) produced 8 amps and 30 volts…



Note: these diagrams are very basic in order to explain the concept of series versus parallel connections. Most modern-day systems are required to also include rapid shutdown components (such components are not shown here).

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Inverters

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Inverters

- Inverters are required for PV systems in order to convert DC power into AC power.
- In most cases, inverter's AC output voltage for residential use is 240V single phase.

Solaredge® String Inverter

SMA® SunnyBoy™ String Inverter

Enphase® IQ7+™ Micro inverter

AP Systems® YC600 Micro inverter

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Inverters

- For commercial use, inverter's AC output voltage can be 208V, 240V, 277V, or 480 volts for 3 phase systems (depending on the model).

SolarEdge® SE66.6kUS

SMA® Tripower Core1-US

Advanced Energy®100kw inverter

Solectria® 60-95 kw inverter

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Utility Interactive Inverters

- Any PV Inverters (commercial or residential) that are interconnected with the electric utility grid must meet UL 1741 and be listed as "utility interactive" having anti-islanding protection, *NEC* 705.40.

Solaredge® String Inverter

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Rapid Shutdown

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Rapid Shutdown

690.12(B) Controlled Limits:

- The use of the term **array boundary** in this section is defined as **(1 ft) from the array in all directions (and 3' into the attic)**. Controlled conductors outside the array boundary shall comply with *NEC* 690.12(B)(1) and inside the array boundary shall comply with 690.12(B)(2).

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Rapid Shutdown

- **(B)(1) Outside the Array Boundary.** "Controlled conductors located outside the boundary or more than **(3 ft)** from the point of entry inside a building shall be limited to not more than **30 volts within 30 seconds** of rapid shutdown initiation. Voltage shall be measured between any two conductors and between any conductor and ground."

18

Rapid Shutdown

690.12(B)(2) Inside the Array Boundary:

- The PV system must comply with *one* of the following:
  - (1) "A PV hazard control system listed for the purpose **(per UL 3741)** shall be installed in accordance with the instructions included with the listing or field labeling. Where a hazard control system requires initiation to transition to a controlled state, the rapid shutdown initiation device required in 690.12(C) shall perform this initiation."
  - (2) "Controlled conductors located **inside the boundary** or not more than (3 ft) from the point of penetration of the surface of the building shall be limited to not more than **80 volts within 30 seconds** of rapid shutdown initiation. Voltage shall be measured between any two conductors and between any conductor and ground."
  - (3) "PV arrays shall have no exposed wiring methods, no exposed conductive parts, and be installed more than 2.5 m (8 ft) from exposed grounded conductive parts or ground shall not be required to comply with 690.12(B)(2)."

NFPE 70, National Electrical Code

19

Rapid Shutdown Initiation Device

***NEC* 690.12(C) Initiation Device:**

- For a one-family and two-family dwelling, the initiation device must be located at a **readily accessible** location on the outside of the building.
- The rapid shutdown initiation device(s) shall consist of at least one of the following:
  - (1) Service disconnecting means.
  - (2) PV system disconnecting means.
  - (3) Readily accessible switch that plainly indicates whether it is in the "off" or "on" position.

Where multiple PV systems are installed with rapid shutdown functions on a single service, the initiation device(s) shall consist of not more than six switches or six sets of circuit breakers, or a combination of not more than six switches and sets of circuit breakers, mounted in a single enclosure, or in a group of separate enclosures.

20

Rapid Shutdown Initiation Device

Example of an older type of rapid shutdown initiation device – "Birdhouse" solar shut-off device by MidNite Solar

Pushbutton switch

Breaker

The type of rapid shutdown initiation device used will depend on the type of rapid shutdown components of the system.

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Examples of Rapid Shutdown Equipment

2020 *NEC* 690.12(D) Equipment:

- Equipment that performs the rapid shutdown functions, **other than** initiation devices such as listed disconnect switches, circuit breakers, or control switches, shall be listed for providing rapid shutdown protection.

Tigo® TS4-R-S DC to DC converter

Enphase® micro inverter

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Rapid Shutdown Signage

- **690.56(C) - Buildings with Rapid Shutdown.** Buildings with PV systems shall have permanent labels as described in 690.12(D)

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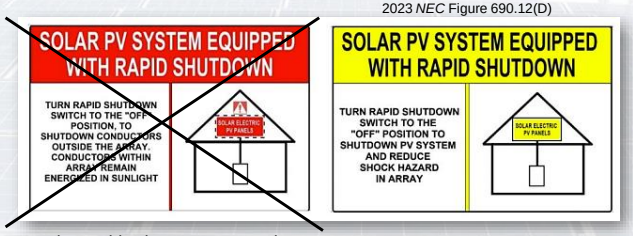
Rapid Shutdown Signage

2020 *NEC* Figure 690.56(C), and 2023 *NEC* Figure 690.12(D)



(note: this sign was removed from the 2020 *NEC*)

See also 1205.4 in the 2021 *IFC* for similar requirements.

24

Rapid Shutdown Signage For Buildings with More Than One Rapid Shutdown Type

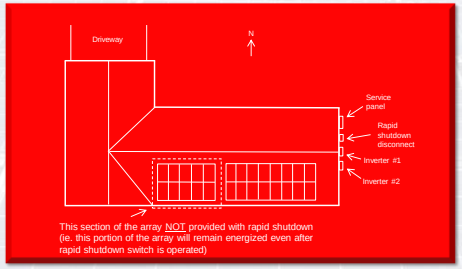
***NEC* 690.56(C)(1) - Buildings with More Than One Rapid Shutdown Type:**

- For buildings that have PV systems with more than one type of rapid shutdown, **or** a PV system with a rapid shutdown type and a PV system with no rapid shutdown, a detailed plan view diagram of the roof shall be provided showing each different PV system and a dotted line around areas that remain energized after the rapid shutdown switch is operated.

25

Rapid Shutdown Signage For Buildings with More Than One Rapid Shutdown Type

Example of a plaque showing which portion(s) of the PV system are equipped with rapid shutdown and which are not:



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Rapid Shutdown Switch Signage

- ***NEC* 690.56(C)(2) Rapid Shutdown Switch.** A rapid shutdown switch shall have a label located on or no more than (3 ft) from the switch that includes the following wording: **"RAPID SHUTDOWN SWITCH FOR SOLAR PV SYSTEM"**
- The label shall be reflective, with all letters capitalized and having a minimum height of 9.5 mm (3⁄8 in.), in white on red background.

Sign located next to the rapid shutdown disconnect (and must be reflective)

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Micro Inverter Systems VS String Inverter Systems

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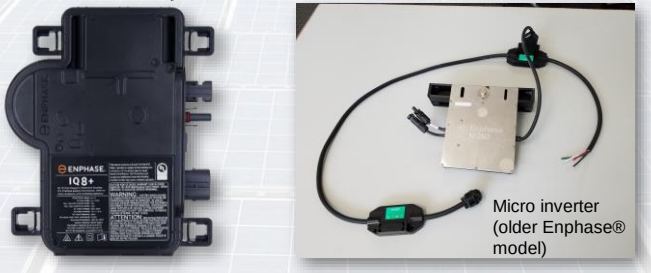
Enphase® Micro inverters



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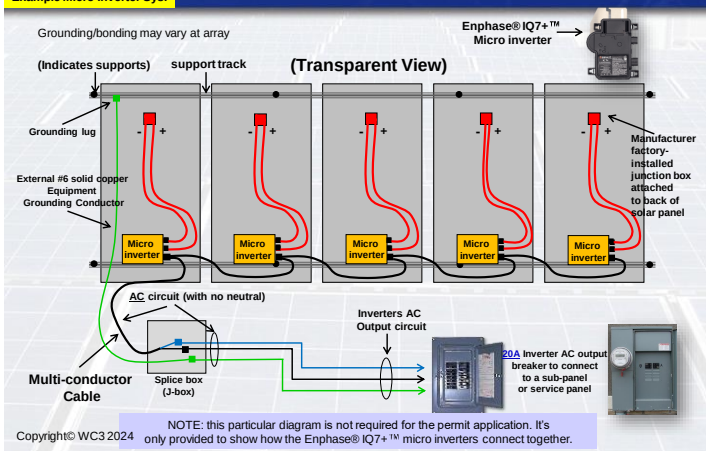
Enphase® IQ7+™ Micro Inverter System

Example Micro Inverter Sys.



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NOTE: this particular diagram is not required for the permit application. It's only provided to show how the Enphase® IQ7+™ micro inverters connect together.

30

Enphase® Micro inverters

(+ and -) DC leads coming out of back of solar panel (these wires cannot be shut down but typically will not have a voltage over 30-40V DC)

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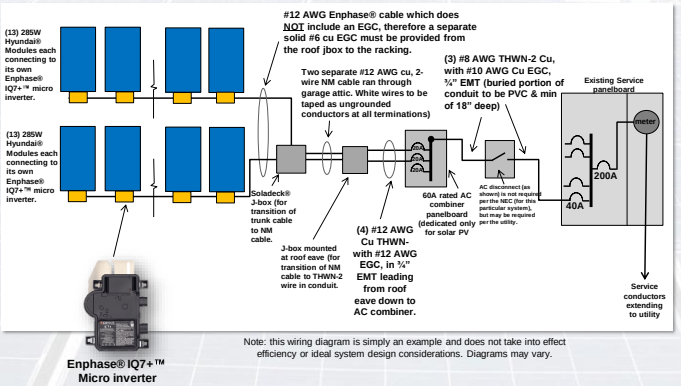
Example System (for an Enphase® IQ7+™ micro inverter system)

Example Micro Inverter Sys.



Note: this wiring diagram is simply an example and does not take into effect efficiency or ideal system design considerations. Diagrams may vary.

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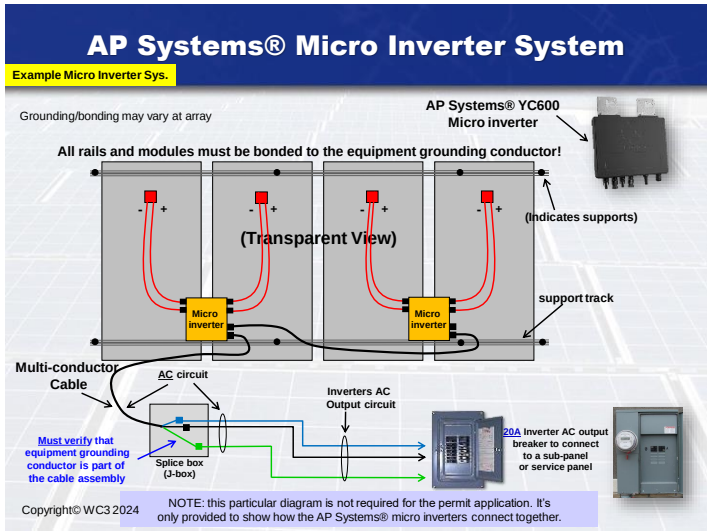
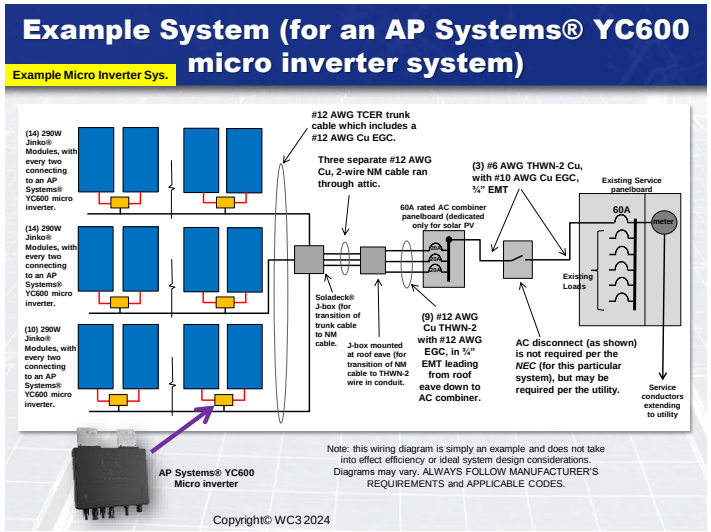

AP Systems® Micro Inverter System
Example Micro Inverter Sys.
Grounding/bonding may vary at array
AP Systems® YC600 Micro inverter
All rails and modules must be bonded to the equipment grounding conductor!
(Indicates supports)
(Transparent View)
support track
Micro inverter
Micro inverter
Multi-conductor Cable
AC circuit
Inverters AC Output circuit
Must verify that equipment grounding conductor is part of the cable assembly
Splice box (J-box)
20A Inverter AC output breaker to connect to a sub-panel or service panel
Copyright© WC3 2024
NOTE: this particular diagram is not required for the permit application. It's only provided to show how the AP Systems® micro inverters connect together.

33


Example System (for an AP Systems® YC600 micro inverter system)
Example Micro Inverter Sys.
(14) 290W Jinko® Modules, with every two connecting to an AP Systems® YC600 micro inverter.
(14) 290W Jinko® Modules, with every two connecting to an AP Systems® YC600 micro inverter.
(10) 290W Jinko® Modules, with every two connecting to an AP Systems® YC600 micro inverter.
#12 AWG TCER trunk cable which includes a #12 AWG Cu EGC.
Three separate #12 AWG Cu, 2-wire NM cable ran through attic.
(3) #6 AWG THWN-2 Cu, with #10 AWG Cu EGC, ¾" EMT
Existing Service panelboard
60A
meter
60A rated AC combiner panelboard (dedicated only for solar PV
Existing Loads
Soladeck® J-box (for transition of trunk cable to NM cable.
J-box mounted at roof eave (for transition of NM cable to THWN-2 wire in conduit.
(9) #12 AWG Cu THWN-2 with #12 AWG EGC, in ¾" EMT leading from roof eave down to AC combiner.
AC disconnect (as shown) is not required per the NEC (for this particular system), but may be required per the utility.
Service conductors extending to utility
AP Systems® YC600 Micro inverter
Note: this wiring diagram is simply an example and does not take into effect efficiency or ideal system design considerations. Diagrams may vary. ALWAYS FOLLOW MANUFACTURER'S REQUIREMENTS and APPLICABLE CODES.
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String inverters
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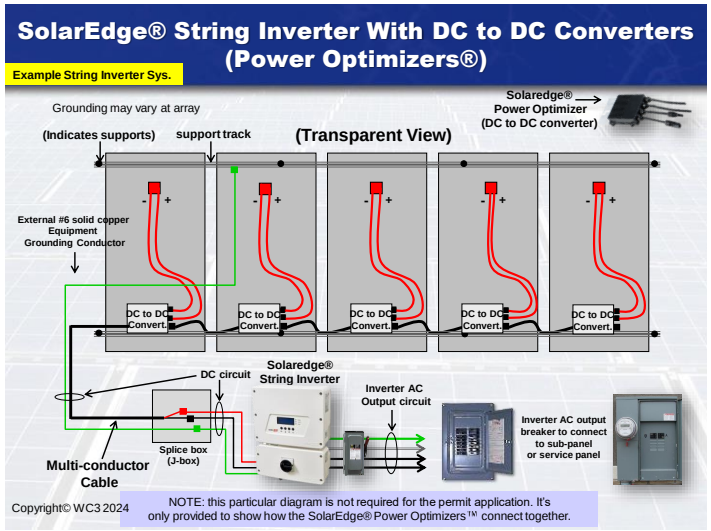
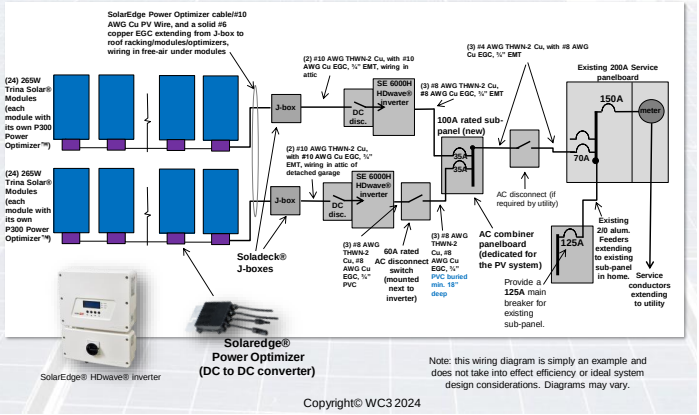

SolarEdge® String Inverter With DC to DC Converters (Power Optimizers®)
Example String Inverter Sys.
Grounding may vary at array
Solaredge® Power Optimizer (DC to DC converter)
(Indicates supports)
support track
(Transparent View)
External #6 solid copper Equipment Grounding Conductor
DC to DC Convert.
DC circuit
Solaredge® String Inverter
Inverter AC Output circuit
Splice box (J-box)
Multi-conductor Cable
Inverter AC output breaker to connect to sub-panel or service panel
Copyright© WC3 2024
NOTE: this particular diagram is not required for the permit application. It's only provided to show how the SolarEdge® Power Optimizers™ connect together.

36

A SolarEdge® system (with two HDwave® SolarEdge® inverters)

Example String Inverter Sys.



Note: this wiring diagram is simply an example and does not take into effect efficiency or ideal system design considerations. Diagrams may vary.

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SolarEdge® String inverters

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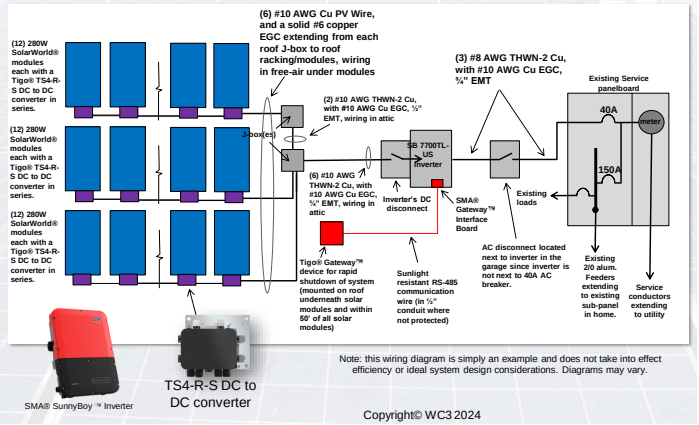
Example Single-Line Diagram (for an SMA® inverter with full rapid shutdown equipment)



Note: this wiring diagram is simply an example and does not take into effect efficiency or ideal system design considerations. Diagrams may vary.

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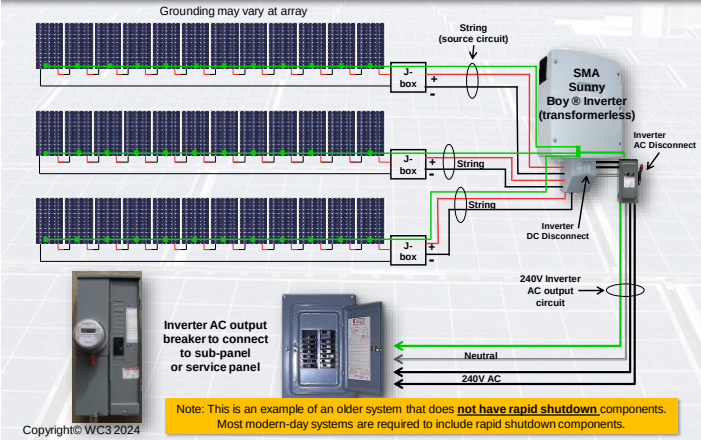
Example System – Older String Inverter

Example String Inverter Sys.



Note: This is an example of an older system that does **not have rapid shutdown** components. Most modern-day systems are required to include rapid shutdown components.

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Carports/Shade Structures



Per the 2023 *NEC*, Section 690.12, non-enclosed detached structures do <u>NOT</u> require rapid shutdown functionality.

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DC Ground Fault Protection (GFPD)

- PV systems operating at over 30V DC or 8 amps are required to have DC ground fault protection, *NEC* 690.41(B).
- Most PV inverters incorporate a DC GFPD (always verify with the inverter manufacturer!).


Solaredge®


SMA® SunnyBoy™ Inverter

Note: even micro inverters are required to have listed DC ground fault protection.

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Tesla® Shingles
(often considered as BIPV)

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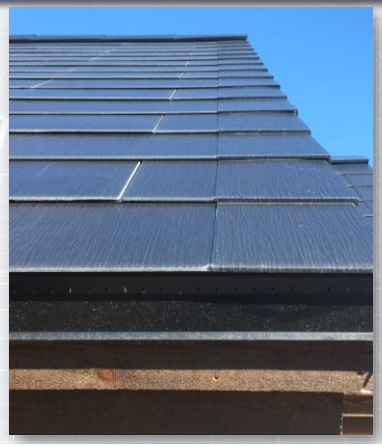
Tesla® Shingles

Tesla® shingle systems are required to have what Tesla calls middle circuit interrupters (MCIs) throughout the solar array in order for the system to be rapid shutdown compliant.



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IRC Roof Access Provisions (per the 2021 *IRC*)

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Roof Access For Venting

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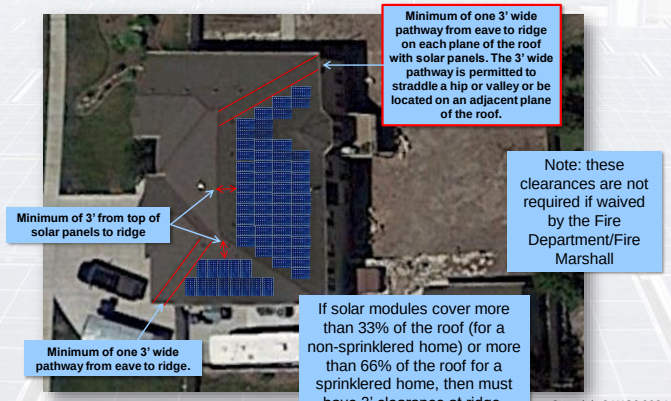
Roof Fire Access (2021 *IRC* Section R324.6)



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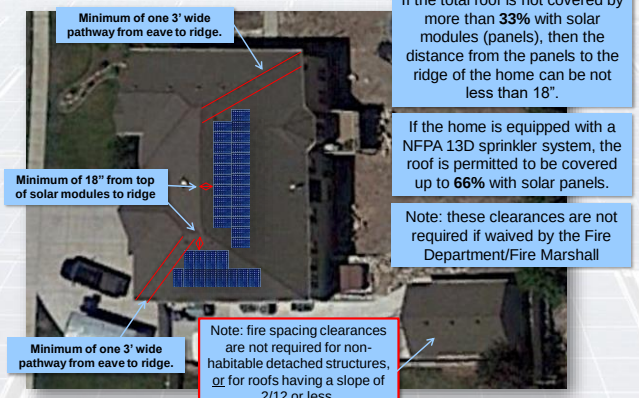
Roof Fire Access (2021 *IRC* Section R324.6)



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Access to Egress Openings (IRC R324.6.3)

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Wiring Methods

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Wire Types

- For PV DC circuits exposed outside, listed "PV wire" or USE-2 and RHW-2 wire must be used (and marked as sunlight resistant), *NEC* 690.31(C)(1).
- Cables to be secured every 24" using listed ties, straps, hangers, etc., where exposed.
- Wiring is also required to be protected from physical damage per *NEC* 300.4

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Installation Errors

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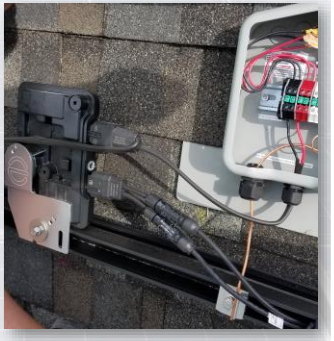
690.31(C)(3) Multiconductor Cable

Multiconductor Cables:

- Where part of a listed PV assembly, multiconductor jacketed cables shall be installed in accordance with the included instructions.
- Where not part of a listed assembly, or where not otherwise covered in the *NEC*, multiconductor jacketed cables, including DG cable, shall be installed in accordance with the product listing and shall be permitted in PV systems and must meet the requirements of items 690.31(C)(3)(1) and (C)(3)(2).



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Wire Protection
(where DC conductors are readily accessible)

***NEC* 690.31(A):**

- Where PV source and output circuits operating at voltages greater than 30 volts are installed in readily accessible locations, circuit conductors shall be **guarded or installed in Type MC cable or in raceway**.

"Guarded circuit conductors?

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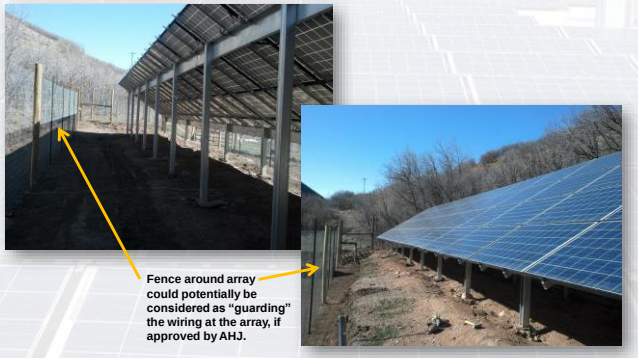
Wire Protection
(where DC conductors are readily accessible)



Fence around array could potentially be considered as "guarding" the wiring at the array, if approved by AHJ.

Wires located in readily accessible locations shall be installed in raceways, MC cable, or be guarded, *NEC* 690.31(A).

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Accessible DC Wiring?

Ground-mount solar array – DC wires guarded?

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Wiring Methods

690.31(D) – DC Circuits in/on Buildings:

- Whenever dc circuits for PV systems operate over 30V or 8 amps and are inside a building, such circuits must be in metal raceways, MC cable, or metal enclosures.
  - New exception: Non-metallic enclosures, raceways, or cables that are part of a listed PV hazard control system are permitted at the point of penetration of the building to the PV hazard control actuator.

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Wiring Methods

690.31(D)(2) – Markings/Labels:

- There must be provided labels on the exterior of all exposed raceways, enclosures, boxes, and conduit bodies. The wording of the labels must state either of the following: "PHOTOVOLTAIC POWER SOURCE" or "SOLAR PV DC CIRCUIT."

PHOTOVOLTAIC POWER SOURCE

Or

SOLAR PV DC CIRCUIT

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Grounding and Bonding

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Grounding and Bonding of Equipment

Equipment to be grounded:

- ***NEC* 690.43:** The metal parts of all modules, support rails, elect. boxes, and other equipment associated with the PV system must be bonded together and connected to an equipment grounding conductor.
- **690.43(A):** Devices and systems used for mounting PV modules that are also used for bonding module frames shall be listed, labeled, and identified for bonding PV modules. Devices that mount adjacent PV modules shall be permitted to bond adjacent PV modules.

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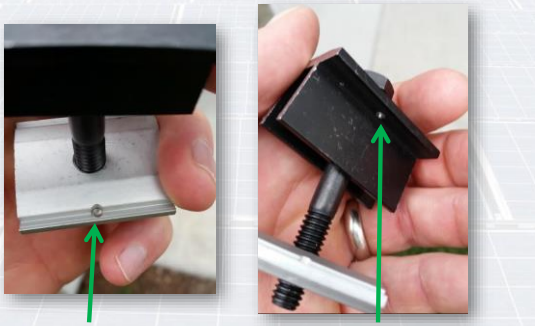
Racking With Integrated Bonding

SnapNrack® racking with integrated bonding



Bonding ring digs into rails

T-clamp pin digs into the PV modules (panels)

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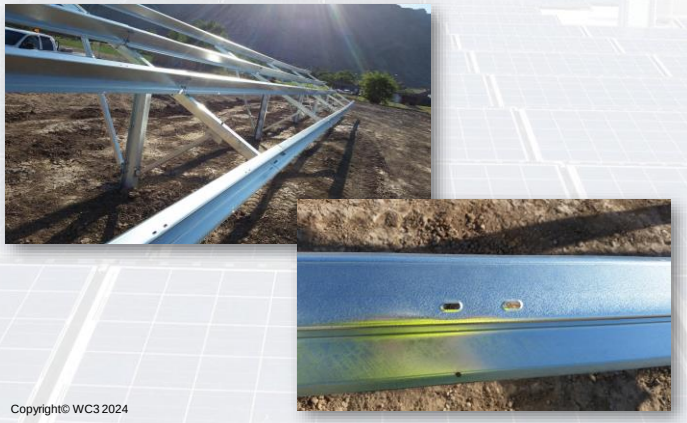
61

Ground-Mounted System Racking With Integrated Bonding



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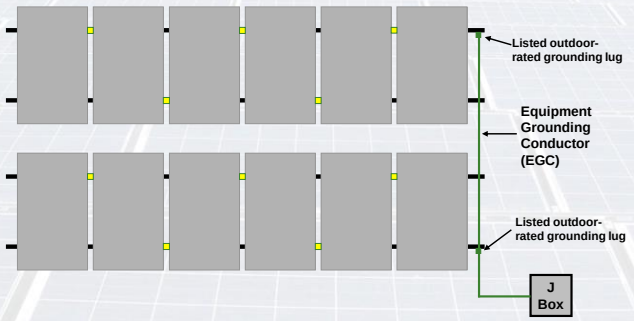
62

Bonding Metal Parts To The Equipment Grounding Conductor (EGC)

= Listed device for bonding frames of solar panels to support rails



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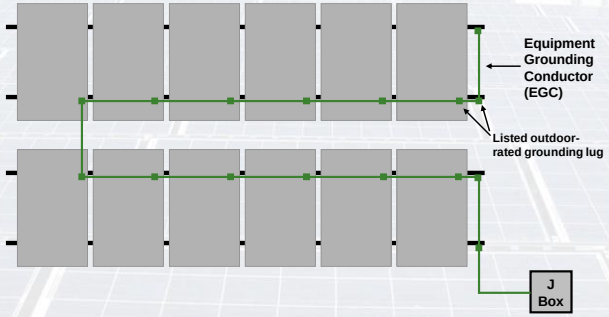
Bonding Supports And Modules



If listed bonding devices are not used, each module and each rail must be individually connected to the equipment grounding conductor.

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Grounding and Bonding

690.45 – Size of EGCs:

- 690.45 of the 2020 *NEC* notes that it is <u>not</u> required to increase the size of the equipment grounding conductor (EGC) to address voltage drop considerations.

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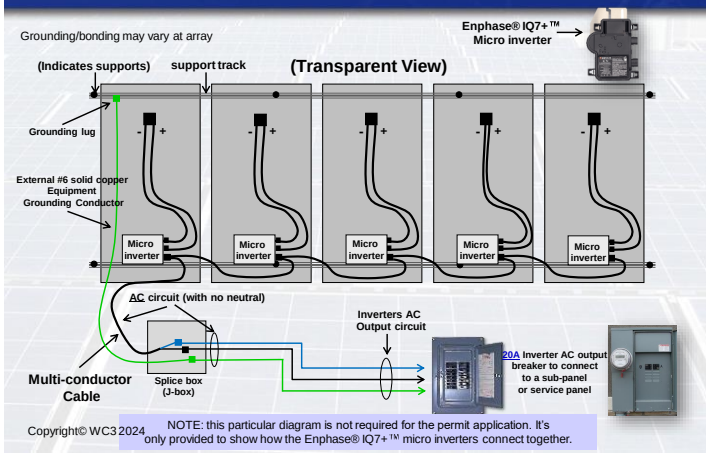
Grounding and Bonding

2020 *NEC* 690.47(A) - Grounding Electrode System:

- A building or structure that supports a PV system must have a grounding electrode system (per Part III of *NEC* Article 250).
- For connection of the PV system to the grounding electrode system, either of the applicable following methods must be used:
  - PV systems that are <u>NOT</u> solidly grounded (<u>such as functionally grounded systems</u>) the equipment grounding conductor (EGC) of inverter's ac output circuit is permitted to be the only connection to ground for the PV system when such equipment ground wire is connected to a distribution system that is already connected to a grounding electrode system.
  - The second option applies to solidly grounded PV systems (see 690.47(A)(2). These systems are very rare.

66

Enphase® IQ7+™ Micro Inverter System



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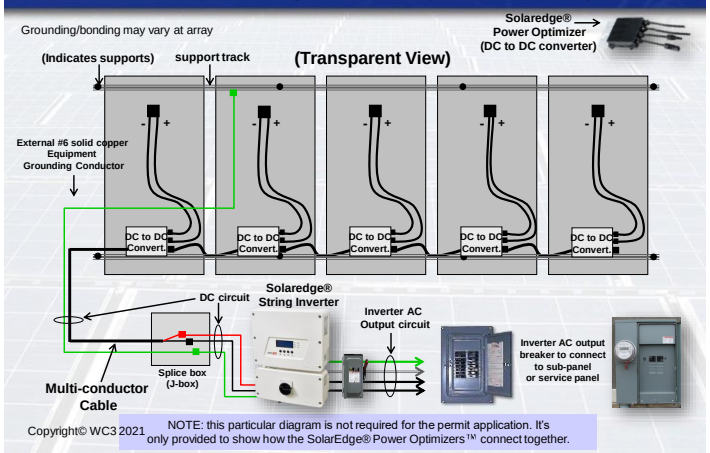
NOTE: this particular diagram is not required for the permit application. It's only provided to show how the Enphase® IQ7+™ micro inverters connect together.

67

Solaredge® String Inverter With DC to DC Converters (Power Optimizers®)



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NOTE: this particular diagram is not required for the permit application. It's only provided to show how the SolarEdge® Power Optimizers™ connect together.

68

Point of Interconnection Requirements (Article 705)

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Splices and Taps

230.46 – Splices and Taps

- Any pressure connectors and devices for splicing or taps onto service conductors must be marked "suitable for use on the line side of the service equipment," or equivalent wording.

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Multiple Sources of Power

705.10 – Identification of Power Sources:

- A permanent plaque or directory is required to be installed at each service equipment location (or other readily visible location). Such must denote the location of each power source disconnecting means for the building or structure and be grouped with any other plaques or directories.
- Such plaque or directory must be marked with the words "CAUTION: MULTIPLE SOURCES OF POWER."

71

Point Of Interconnection

Connecting The PV System To The Bld's Elect. System:

- There are 2 general places a PV system can *potentially* connect to a building's electrical system:
  - On the supply side (line side) of the building's main service disconnect.
  - On the load side of the building's main service disconnect.

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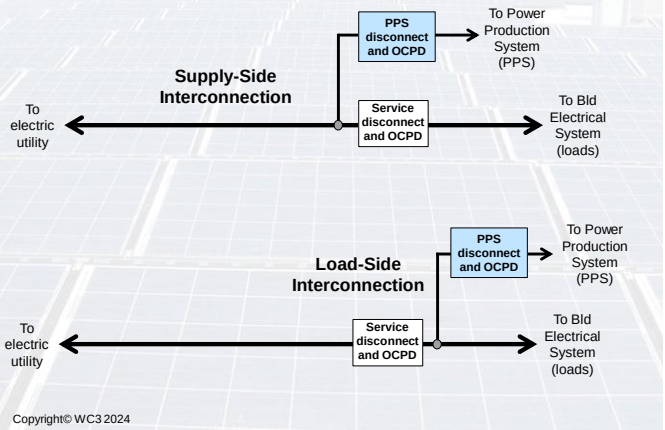
Supply (line) Connections Vs Load Connections



73

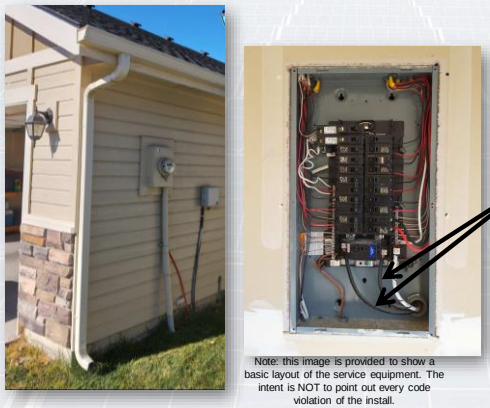
Supply (Line) Side Connection

***NEC* 705.11:**

- An electric power production source is permitted to be connected on the supply side of a service disconnecting means per 230.82(6). Such interconnection must also comply with the other requirements of 705.11.
  - Note: 230.82(6) specifies that solar PV systems are permitted to be on the supply side of the service disconnecting means if the PV system disconnecting means is listed as suitable for use as service equipment.

74

Supply-Side Interconnection



Note: this image is provided to show a basic layout of the service equipment. The intent is NOT to point out every code violation of the install.

A power production system connection to these service-entrance conductors is ONE example of a supply-side interconnection.

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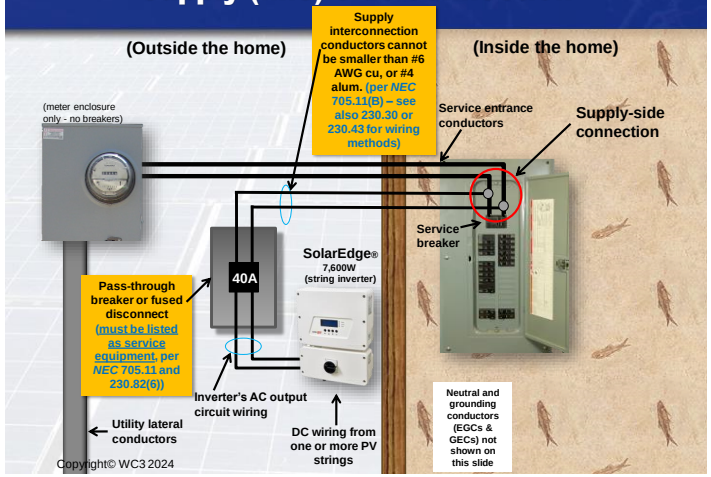
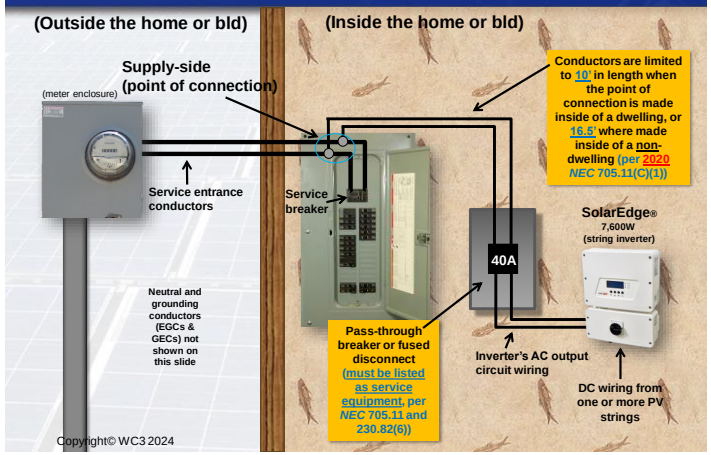
Supply (line) side connection



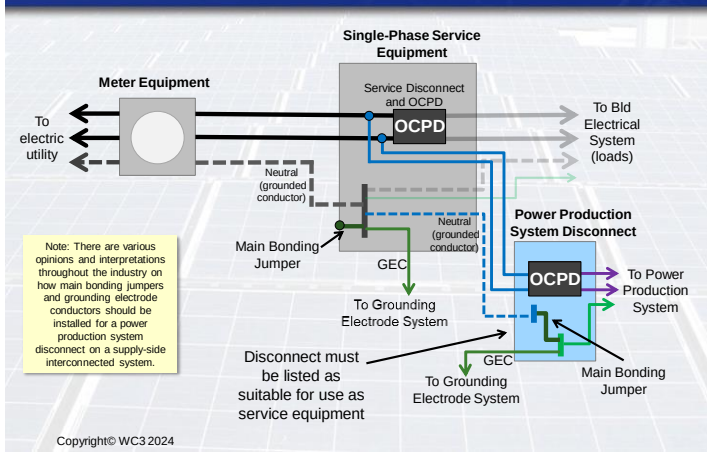
76

Supply (line) side connection (2020 *NEC*) – Made Inside of a Building



77

Section 250.25 of the 2020 & 2023 *NEC* (example)



78

Supply (line) side connection continued…

- This particular Square D service meter-main combo panelboard allows for supply-side interconnections to be made to the busbars located above the main breaker (see Square D model SC2040M200PS)

Note: this image is provided to show a basic layout of the service equipment. The intent is NOT to point out every code violation of the install.

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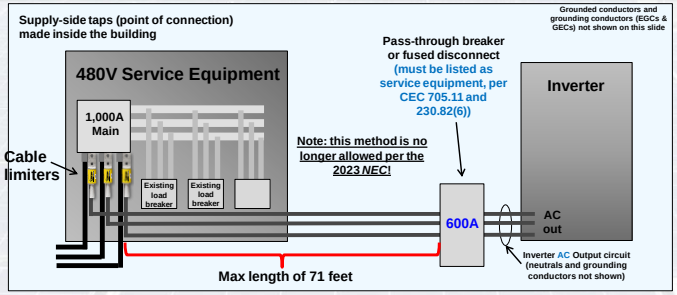
Supply (line) side connection (2020 *NEC*) – Made Inside of a Building



For non-dwellings, the overcurrent protection device can be located within 71 feet (maximum conductor length) as long as cable limiters are provided for each ungrounded conductor. The cable limiters would need to be within 16.5 feet of the point of connection (maximum conductor length).

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Supply (line) side connection continued…

Cooper Bussman cable limiter

Ferraz Shawmut cable limiters

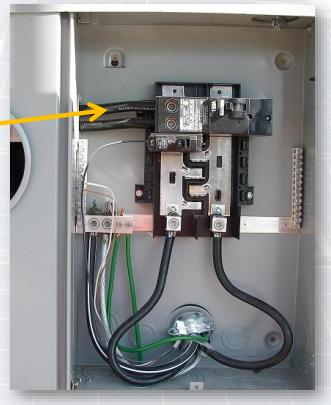
Examples of cable limiters

81

705.11(D) EXAMPLE

Example: does the manufacturer of this service panel allow the factory installed wiring to be tapped?

Does it violate the installation instructions and listing of the equipment?



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Supply (Line) side connection continued…

What about supply-side connections made with a breaker?

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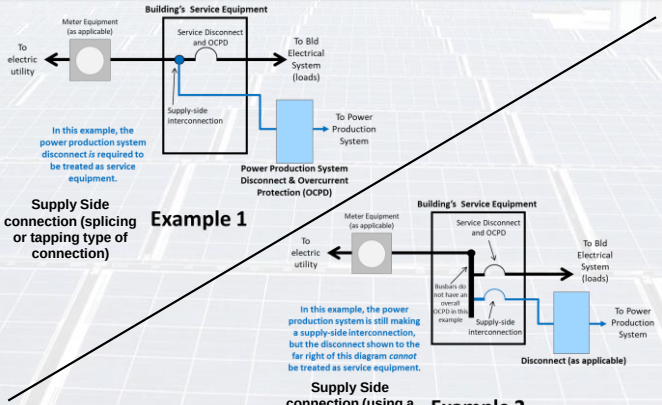
Supply (Line) side connection continued…



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When Overcurrent Protection is Provided at the Supply End of the Conductors

In this scenario any disconnect or panelboard on the *load* side of the service breaker is NOT treated as service equipment, NOR can there be any neutral-to-ground bonding connections in it/them.

(disconnect switch, panelboard, etc.)

To Power Production System

NOT SERVICE EQUIPMENT

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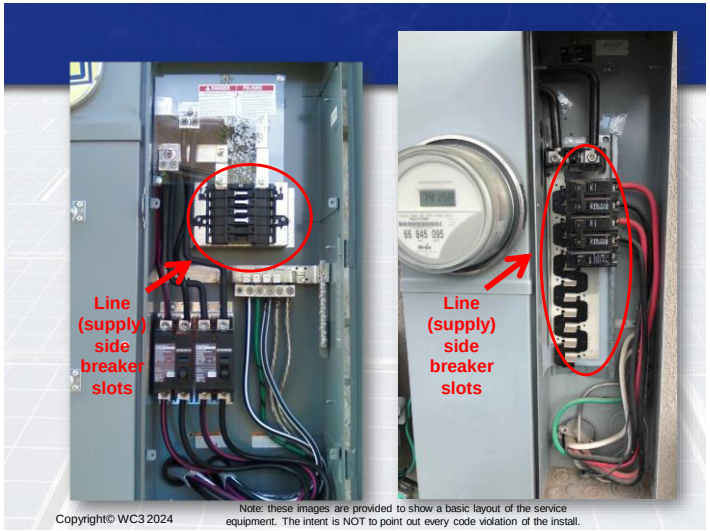

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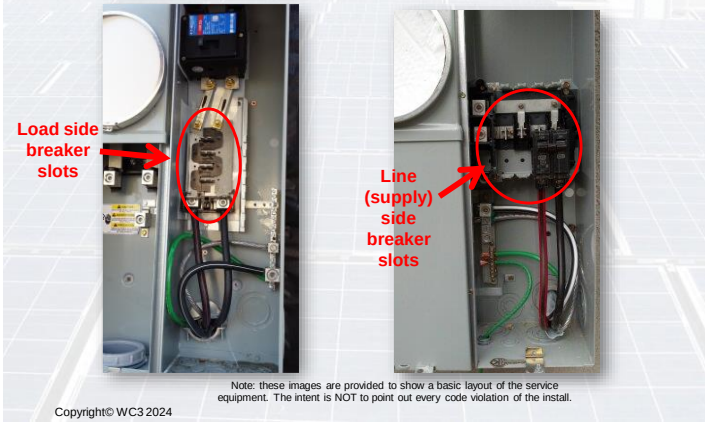
Note: these images are provided to show a basic layout of the service equipment. The intent is NOT to point out every code violation of the install.

86

Example service panelboards



Note: these images are provided to show a basic layout of the service equipment. The intent is NOT to point out every code violation of the install.

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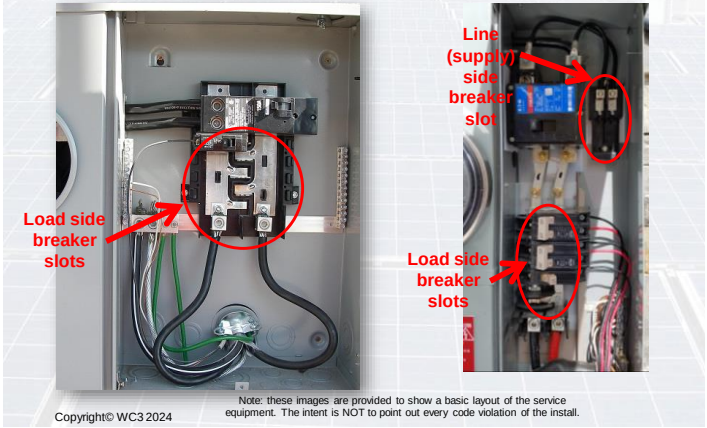
Example service panelboards



Note: these images are provided to show a basic layout of the service equipment. The intent is NOT to point out every code violation of the install.

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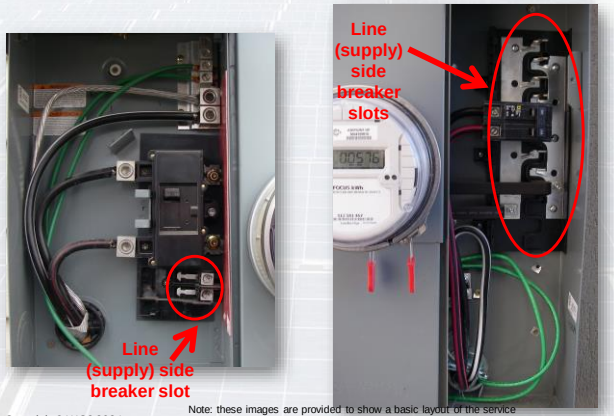
Example service panelboards



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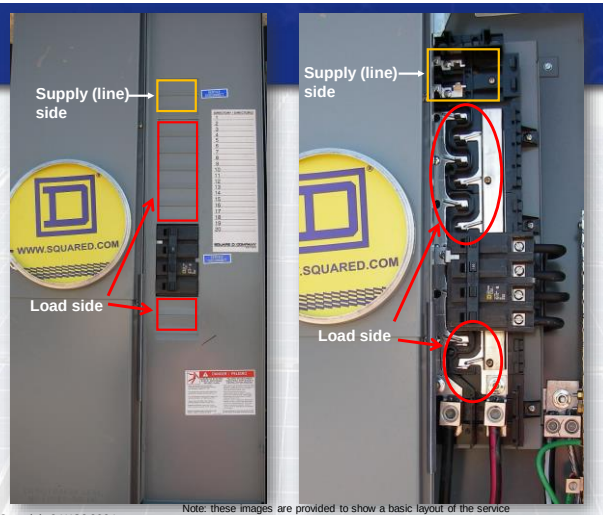
Note: these images are provided to show a basic layout of the service equipment. The intent is NOT to point out every code violation of the install.

89

Example service panelboards



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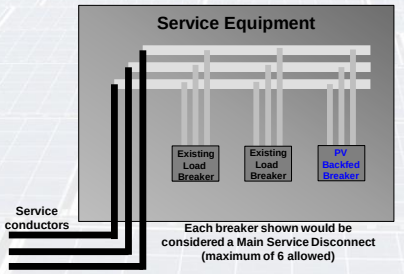
Note: these images are provided to show a basic layout of the service equipment. The intent is NOT to point out every code violation of the install.

90

Supply (line) Side Of Main Service Disconnect (for large service equipment)

Grounded conductors and grounding conductors (EGCs & GECs) not shown on this slide



The PV backfed breaker could be as large as the rating of the service conductors IF the service equipment manufacture's listing allows that size of breaker to be connected at the breaker slot.

Supply-side connections are allowed per *NEC* 705.11.

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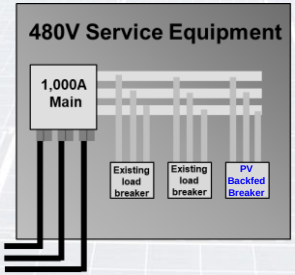
Load-Side Connections

Grounded conductors and grounding conductors (EGCs & GECs) not shown on this slide



Load-side connections need to comply with the requirements of *NEC* 705.12(B).

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Load Side Connections – 705.12

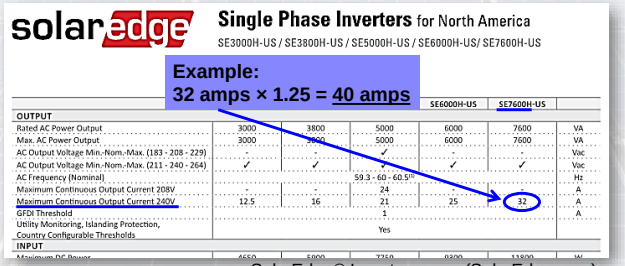
- Load side connections occur on the building's side of the main electrical service disconnect(s).
- **For the purposes of this presentation, the methods of load side interconnections per the 2020 *NEC* will be shown on the following slides.**

93

705.12(A) or (B) - Bus or Conductor Ampacity Rating

Bus or Conductor Calculations:

- 125% of the inverter(s) AC (or "power source") output current is to be used when determining the ampacity calculations of 705.12(B)(1) through (B)(3).



SolarEdge® Inverter specs (SolarEdge.com)

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705.12(B)(1) – Feeders

Feeders

- When an inverter ("power source") connection is made to a feeder, the feeder is required to have an ampacity not less than 125% of the output current (amps) of the inverter(s).
- Per 705.12(B)(1), when the inverter ("power source") AC output connection is made to a feeder at a location **other than** the opposite end of the feeder from the primary source overcurrent device, the portion of feeder on the load side of the inverter ("power source") output connection must be protected by *NEC* 705.12(B)(1)(**a**) or (B)(1)(**b**).

95

705.12(B)(1) (Feeders) continued…

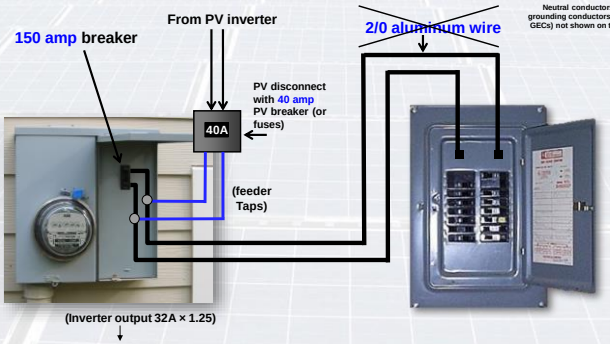
- If the PV connection to a feeder is not at the opposite end of the feeder from the feeder's main breaker (primary overcurrent protection device), the feeder's ampacity on the load side of the PV connection must be as per *NEC* 705.12(B)(1)(**a**) or (B)(1)(**b**):
  - a) The feeder ampacity must not be less than the sum of the primary source OCPD and 125% of the inverter(s) (power source) output current.

    OR
  - b) An overcurrent device on the load side of the inverter (power source) AC output connection must be rated not greater than the ampacity of the feeder.

96

Feeders – Example For Option "a" (*NEC* 705.12(B)(1)(a))

Option "a": The feeder must have an ampacity of the sum of the primary source OCPD and the inverter AC output amps × 1.25:



150A + 40A= 190 amps – 2/0 aluminum is too small!

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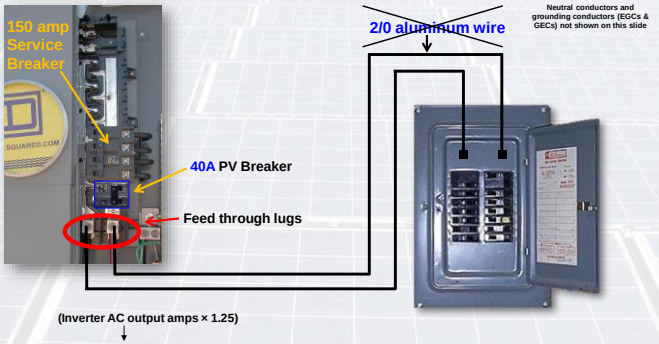
Feeders – Another Example For Option "a" (*NEC* 705.12(B)(1)(a))

Option "a": The feeder wires must have an ampacity of the sum of the primary source OCPD and the inverter AC output amps × 1.25:



150A + 40A= 190 amps – 2/0 aluminum is too small!

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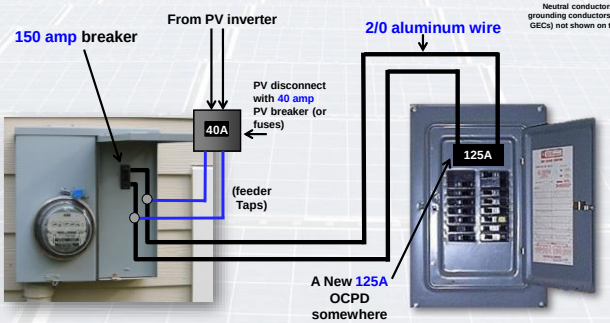
Feeders – Example For Option "b" (*NEC* 705.12(B)(1)(b))

Option "b": An OCPD on the load side of the inverter (power source) connection must be rated not greater than the ampacity of the feeder.



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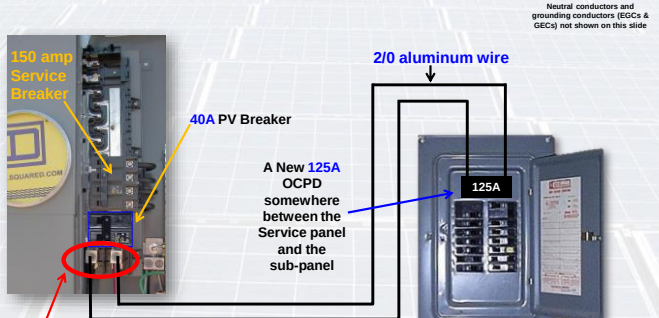
Feeders – Another Example For Option "b" (*NEC* 705.12(B)(1)(b))

Option "b": An OCPD on the load side of the inverter (power source) connection must be rated not greater than the ampacity of the feeder.



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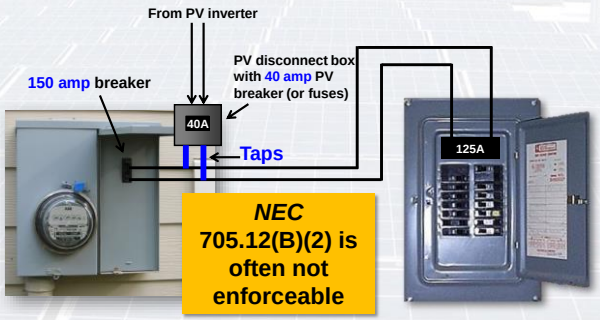
NEC 705.12(B)(2) – Taps

Feeder Taps:

- Where inverter (power source) AC output circuits tap feeder conductors, the **taps** must be sized based on the sum of 125% of the inverter (power source) output circuit current and the rating of the OCPD that is protecting the feeder conductors as calculated per 240.21(B).
- **The above noted code section is very confusing and often is not enforceable. Because of this, consider *NEC* 705.28(B) as an alternate code section for dealing with feeder taps (see next couple slides for explanation):**

101

NEC 705.12(B)(2) – Taps continued…



Strict reading of *NEC* 705.12(B)(2) suggests that the taps shown above must be sized per 150A + 40A= 190 amps!! Is this enforceable?? The taps ampacity must also be as per *NEC* 240.21(B).

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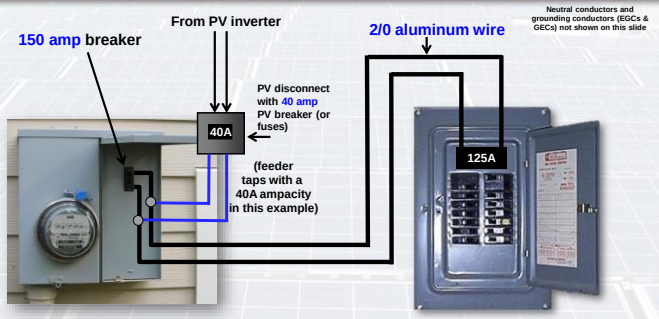
NEC 705.12(B)(2) – Taps (per the 2023 *NEC*)

Feeder Taps:

- Where inverter (power source) AC output circuits tap feeder conductors, the **taps** are to be sized based on 125% of the inverter (power source) output circuit current.
- If either 240.21(B)(2) or (B)(4) will be used (for taps over 10 feet and up to 25 feet long), then the ampacity of the taps cannot be less than 1/3 of the sum of the rating of the OCPD that is protecting the feeder conductors plus the rating of the power source OCPD.

103

NEC 705.12(A)(3) – Taps continued… (per the 2023 *NEC*)



As long as the feeder taps are not over 10 feet long, per *NEC* 705.12(A)(3) the tap conductors must have an ampacity of 125% of the rated output amps of the inverter (which is 40A for a 32A inverter).

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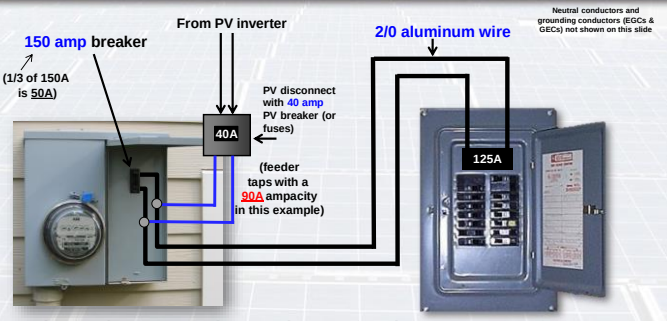
NEC 705.12(A)(3) – Taps OVER 25 Feet Long (per the 2023 *NEC*)



IF the feeder taps are longer than 10 feet but not over 25 feet, per *NEC* 705.12(A)(3) the tap conductors must have an ampacity of at least 1/3 of the 150A main breaker plus the rating of the inverter's OCPD (which is 90A for this example).

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NEC 705.12(B)(3) – Busbars

Busbars

- *NEC* 705.12(B)(3)(1) through (B)(3)(6) must be used for determining the minimum ratings of panelboard busbars.

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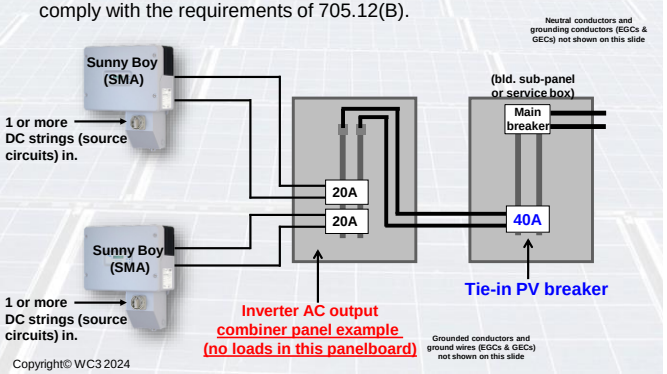
Panelboards with only power source connections (i.e. often called AC combiners)

- It's a common interpretation by AHJs that panelboards which are dedicated only for the PV (and/or ESS) system are not required to comply with the requirements of 705.12(B).



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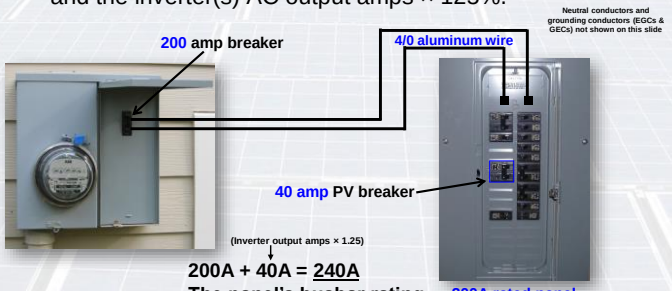
Busbars – Example For Method "1" (*NEC* 705.12(B)(3)(1))

1) The busbars in a panel must be rated for at least the sum of the rating of the OCPD protecting the busbar and the inverter(s) AC output amps × 125%.



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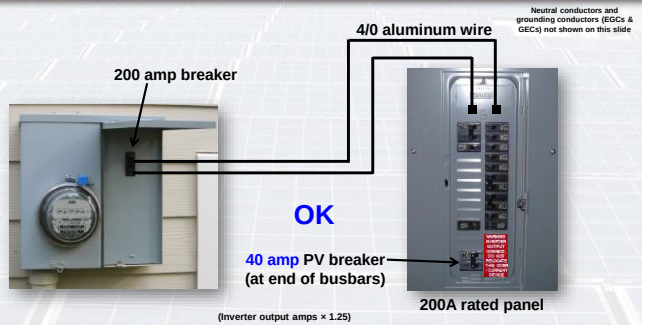
Method "2" (*NEC* 705.12(B)(3)(2))

2) Where two sources, one a utility (primary power source) and the other an inverter (or other power source), are <u>located at opposite ends of a busbar that also has other loads</u>, the sum of the rating of the OCPD protecting the busbar and the inverter(s) (power source) current rating × 125% cannot exceed 120% of the rating of the busbar.
   - The busbars must already be sized for the connected loads as per Article 220 in the *NEC*.
   - A sign must be provided next to the backfed PV breaker stating: "WARNING: POWER SOURCE OUTPUT - DO NOT RELOCATE THIS OVERCURRENT DEVICE"

109

Example for method "2" (*NEC* 705.12(B)(3)(2))



200A + 40A = 240A

200A rated panel × 120% = up to 240 amps allowed

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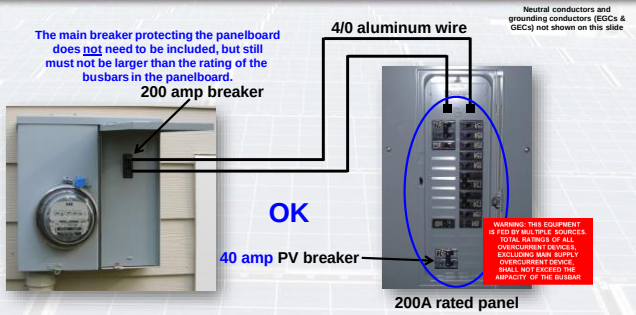
Method "3" (*NEC* 705.12(B)(3)(3))

3) The sum of the ampere ratings of all breakers (OCPDs) on panelboards, including load and supply breakers (but <u>NOT</u> counting the main breaker protecting the panel), must not exceed the rating of the panelboard's busbars.
   - The rating of the main breaker protecting the panelboard must not exceed the rating of the busbars.
   - Permanent warning label must be applied to the panel (distribution equipment) with the words: "WARNING: EQUIPMENT FED BY MULTIPLE SOURCES. TOTAL RATINGS OF ALL OVERCURRENT DEVICES, EXCLUDING MAIN SUPPLY OVERCURRENT DEVICE, SHALL NOT EXCEED THE AMPACITY OF BUSBAR."

111

Example for method "3" (*NEC* 705.12(B)(3)(3))



The combined ratings of all breakers at the above shown panelboard must not exceed the rating of the panelboard's busbars.

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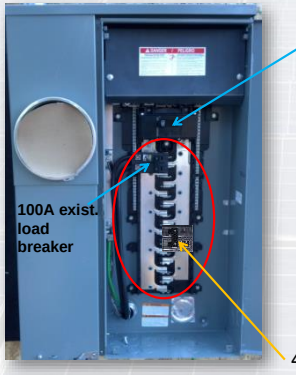
Another example for method "3" (*NEC* 705.12(B)(3)(3))

Note: this image is provided to show a basic layout of the service equipment. The intent is NOT to point out every code violation of the install.



200A rated service panelboard with a 200A main service breaker.

The sum of the breakers in this panel (including the solar PV breaker but NOT counting the main 200A service breaker) could not exceed 200A, per *NEC* 705.12(B)(3)(3).

100A exist. load breaker

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

(Required sign)

40 amp PV breaker

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113

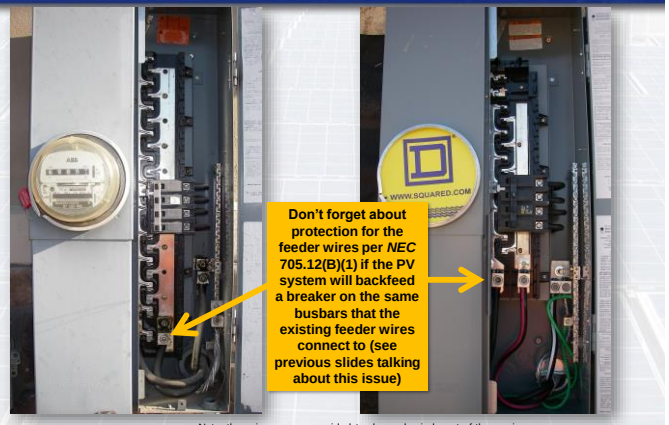
113

Method "4" (*NEC* 705.12(B)(3)(4))

4) A connection at *either* end (but not both ends) of a **center-fed** panel board in dwellings is allowed where the sum of 125 percent of the power source(s) output circuit current and the rating of the overcurrent device protecting the busbar does not exceed 120 percent of the current rating of the busbar.

114

Center-Fed Busbars (dwellings)



Don't forget about protection for the feeder wires per *NEC* 705.12(B)(1) if the PV system will backfeed a breaker on the same busbars that the existing feeder wires connect to (see previous slides talking about this issue)

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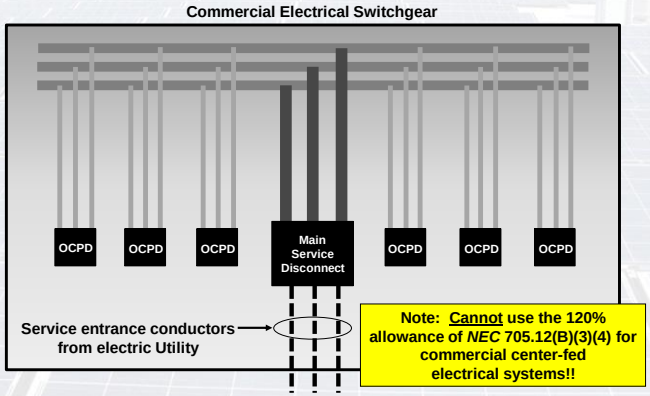
Note: these images are provided to show a basic layout of the service equipment. The intent is NOT to point out every code violation of the install.

115

Example Of Center-Fed Equipment:



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116

Method "5"
(*NEC* 705.12(B)(3)(5))

6) Connections made to switchgear, switchboards, and panelboards that are in configurations differing from *NEC* 705.12(B)(3)(1) through (B)(3)(5) are permitted as long as designed under engineering supervision that includes available fault-current and busbar load calculations.

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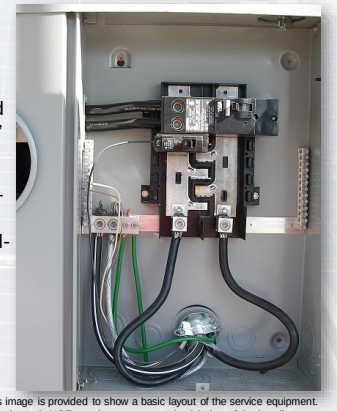
117

Method "6"
(*NEC* 705.12(B)(3)(6))

5) "Connections shall be permitted on busbars of panelboards that supply lugs connected to feed-through conductors. The feed-through conductors shall be sized in accordance with 705.12(B)(1)."

"Where an overcurrent device is installed at either end of the feed-through conductors, panelboard busbars on either side of the feed-through conductors shall be permitted to be sized in accordance with 705.12(B)(3)(1) through (B)(3)(3)."



Note: this image is provided to show a basic layout of the service equipment. The intent is NOT to point out every code violation of the install.

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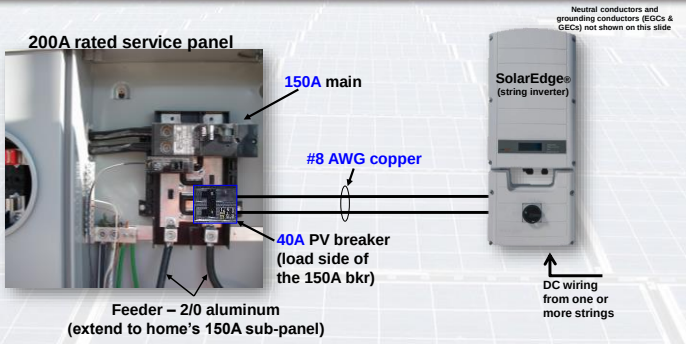
118

Example System



NEC 705.12(B)(1) and (B)(6) violation for the existing 2/0 feeders!
The 2/0 feeders need to be increased to 250kcmil OR a 125A breaker (or fused disconnect) must be added between the service and the existing sub-panel.

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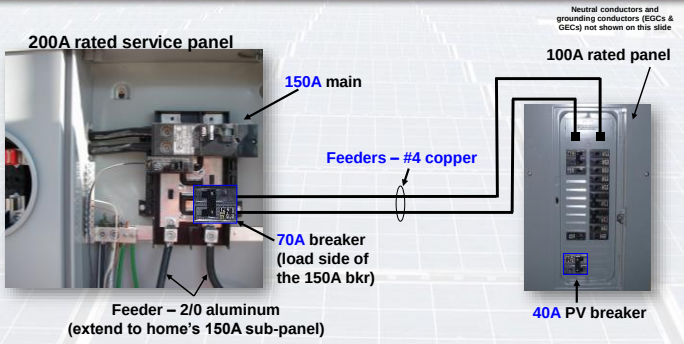
119

Example System



NEC 705.12(B)(1) and (B)(6) violation for the existing 2/0 feeders!

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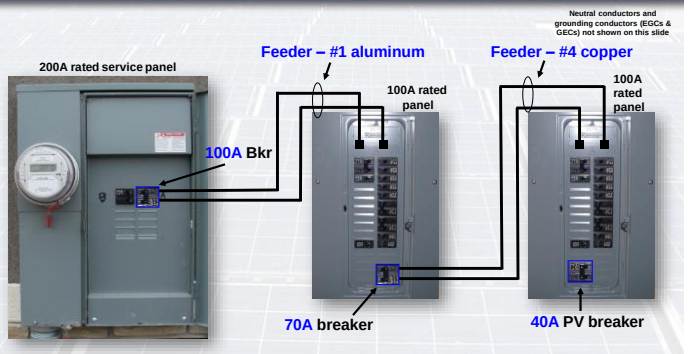
Example System



NEC 705.12(B)(3) violation for the middle panel's busbars!

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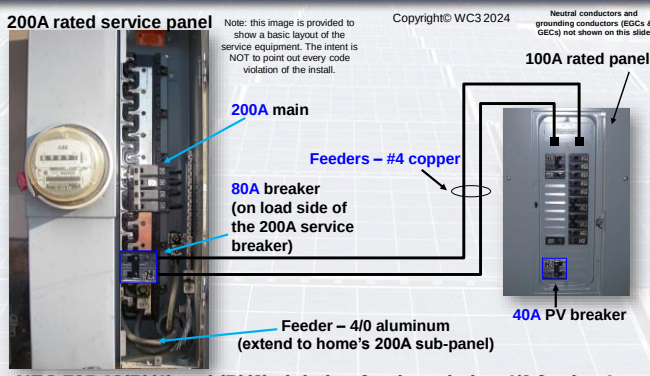
121

Example System



NEC 705.12(B)(1) and (B)(6) violation for the existing 4/0 feeders! Feeders either need to be upsized or must provide overcurrent protection between the service panel and the existing sub-panel.

122

705.13 – Power Control Systems

- **705.13: "**A power control system (PCS) shall be listed and evaluated to control the output of one or more power production sources, energy storage systems (ESS), and other equipment. The PCS shall limit current and loading on the busbars and conductors supplied by the PCS."
- **705.13(E):** "The access to settings of the PCS shall be restricted to qualified personnel in accordance with the requirements of **240.6(C)**."

Note: the requirements of *NEC* 705.13 moved to Article 750 in the 2023 *NEC* (for Energy Management Systems)

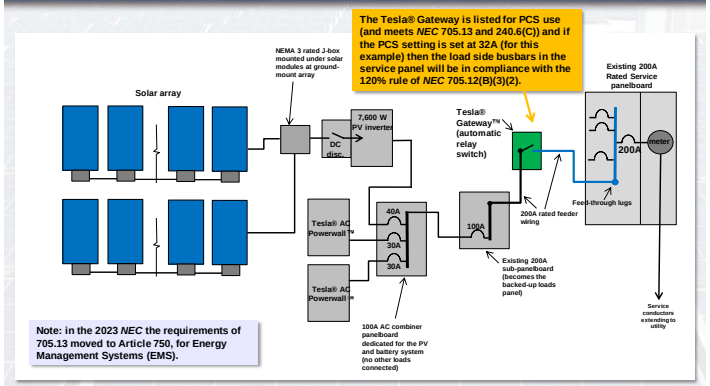
123

Power Control Systems (continued)

- **240.6(C)** requires restricted access to be achieved by one of the following methods:
  - (1) Located behind removable and sealable covers over the adjusting means
  - (2) Located behind bolted equipment enclosure doors
  - (3) Located behind locked doors accessible only to qualified personnel
  - (4) Password protected, with password accessible only to qualified personnel

124

Power Control System (PCS) Example



Note: this wiring diagram is simply an example and does not take into effect efficiency or ideal system design considerations. Diagrams may vary. ALWAYS FOLLOW MANUFACTURER'S REQUIREMENTS and APPLICABLE CODES.

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SolarEdge® Interface Equipment (PCS capability example)

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126

Example Plan Reviews of PV Systems

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127

Plan Review Example System #1

AP Systems® Micro Inverter System

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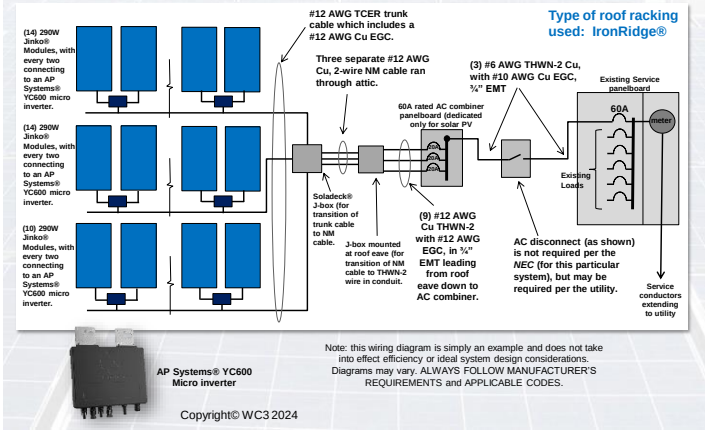
128

Example System (for an AP Systems® YC600 micro inverter system)

Example Sys. #1



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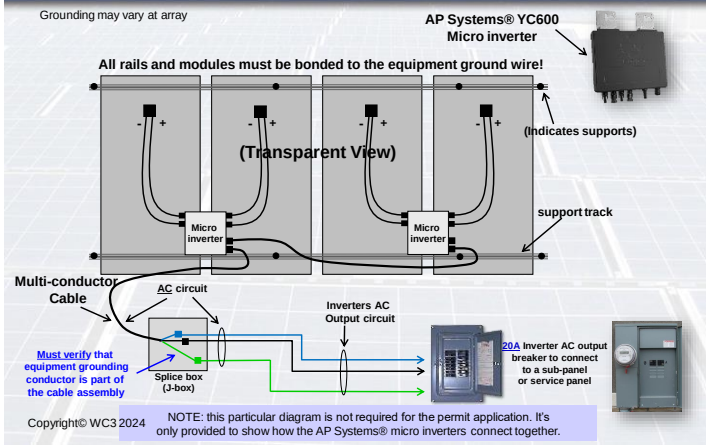
AP Systems® Micro Inverter System

Example Sys. #1



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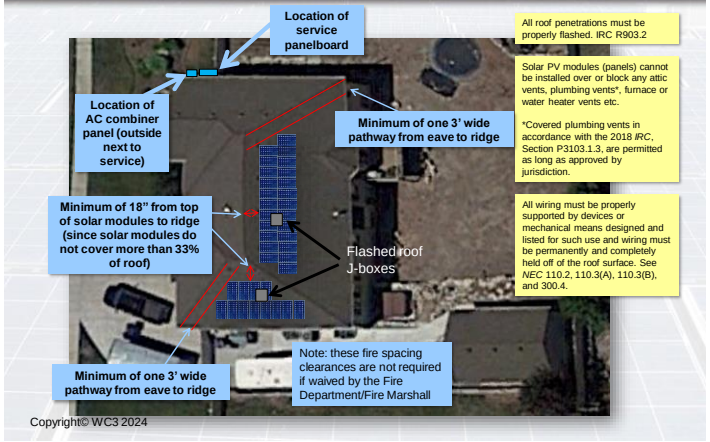
NOTE: this particular diagram is not required for the permit application. It's only provided to show how the AP Systems® micro inverters connect together.

130

Site plan

Example Sys. #1



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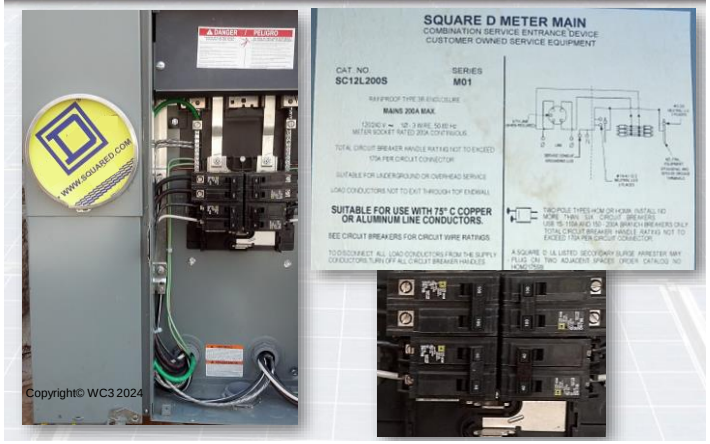
131

Pictures of Service Panel

Example Sys. #1



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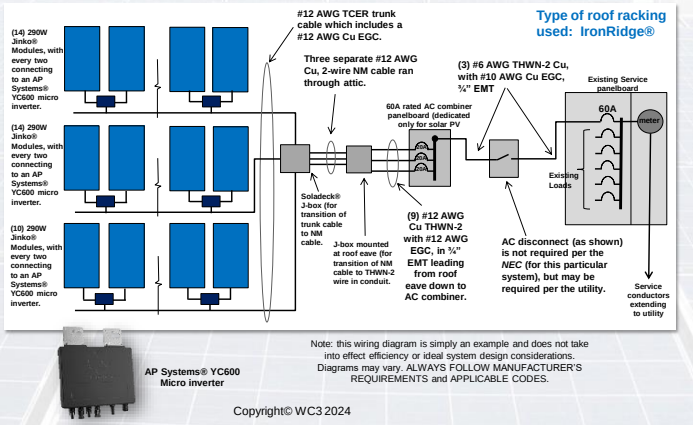
132

Example System (for an AP Systems® YC600 micro inverter system)

Example Sys. #1



Note: this wiring diagram is simply an example and does not take into effect efficiency or ideal system design considerations. Diagrams may vary. ALWAYS FOLLOW MANUFACTURER'S REQUIREMENTS and APPLICABLE CODES.

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133

National Electrical Code© Tables (for wire ampacity deration, if needed)

Example Sys. #1

NEC Table 310.15(B)(16)

Table 310.15(B)(16) (formerly Table 310.16) Allowable Ampacities of Insulated Conductors Rated Up to and Including 2000 Volts, 60°C Through 90°C (140°F Through 194°F), Not More Than Three Current-Carrying Conductors in Raceway, Cable, or Earth (Directly Buried), Based on Ambient Temperature of 30°C (86°F)*

Size AWG or kcmil	Temperature Rating of Conductor [See Table 310.104(A).] 60°C (140°F) Types TW, UF	75°C (167°F) Types RHW, THHW, THWN, XHHW, USE, ZW	90°C (194°F) Types TBS, SA, SIS, FEP, FEPB, MI, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, ZW-2	60°C (140°F) Types TW, UF	75°C (167°F) Types RHW, THHW, THWN, XHHW, USE	90°C (194°F) Types TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHH, XHHW, XHHW-2, ZW-2	Size AWG or kcmil
	COPPER			ALUMINUM OR COPPER-CLAD ALUMINUM			
18**	—	—	14	—	—	—	—
16**	—	—	18	—	—	—	—
14**	15	20	25	—	—	—	—
12**	20	25	30	15	20	25	12**
10**	30	35	40	25	30	35	10**
8	40	50	55	35	40	45	8
6	55	65	75	40	50	55	6
4	70	85	95	55	65	75	4
3	85	100	115	65	75	85	3
2	95	115	130	75	90	100	2
1	110	130	145	85	100	115	1
1/0	125	150	170	100	120	135	1/0
2/0	145	175	195	115	135	150	2/0
3/0	165	200	225	130	155	175	3/0
4/0	195	230	260	150	180	205	4/0
250	215	255	290	170	205	230	250

Since we have (6) current-carrying #12 THWN-2 (90˚C) copper wires in the same conduit (from the eave j-box down to the AC combiner panel), we can use 30A (shown in the 90C column) to start our ampacity deration.
30A × .80= 24A, which #12 AWG cu THWN-2 conductors are still acceptable for our micro inverter circuits)

NEC Table 310.15(B)(3)(a)

Table 310.15(B)(3)(a) Adjustment Factors for More Than Three Current-Carrying Conductors

Number of Conductors[1]	Percent of Values in Table 310.15(B)(16) through Table 310.15(B)(19) as Adjusted for Ambient Temperature if Necessary
4–6	80
7–9	70
10–20	50
21–30	45
31–40	40
41 and above	35

[1]Number of conductors is the total number of conductors in the raceway or cable including spare conductors. The count shall be adjusted in accordance with 310.15(B)(5) and (6). The count shall not include conductors that are connected to electrical components but that cannot be simultaneously energized.

134

National Electrical Code© Tables (for wire ampacity deration, if needed)

Example Sys. #1

NEC Table 310.15(B)(3)(c)

Table 310.15(B)(3)(c) Ambient Temperature Adjustment for Raceways or Cables Exposed to Sunlight on or Above Roofs*

Distance Above Roof to Bottom of Raceway or Cable	Temperature Adder °C	°F
On roof 0 – 13 mm (0 — ½ in.)	33	60
Above roof 13 mm – 90 mm (½ in. – 3½ in.)	22	40
Above 90 mm – 300 mm (3½ in. – 12 in.)	17	30
Above 300 mm – 900 mm (12 in. – 36 in.)	14	25

The table has been removed but conduit on the roof (exposed to sunlight) must still be kept at least **7/8"** above the roof otherwise a **60˚F** temperature added applies (for derating the ampacity of the conductors)

NEC Table 310.15(B)(2)(a)

Table 310.15(B)(2)(a) Ambient Temperature Correction Factors Based on 30°C (86°F)

For ambient temperatures other than 30°C (86°F), multiply the allowable ampacities specified in the ampacity tables by the appropriate correction factor shown below.

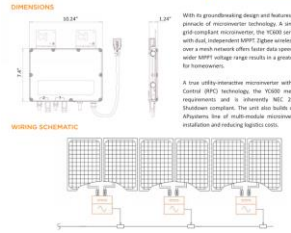
Ambient Temperature (°C)	Temperature Rating of Conductor 60°C	75°C	90°C	Ambient Temperature (°F)
10 or less	1.29	1.20	1.15	50 or less
11–15	1.22	1.15	1.12	51–59
16–20	1.15	1.11	1.08	60–68
21–25	1.08	1.05	1.04	69–77
26–30	1.00	1.00	1.00	78–86
31–35	0.91	0.94	0.96	87–95
36–40	0.82	0.88	0.91	96–104
41–45	0.71	0.82	0.87	105–113
46–50	0.58	0.75	0.82	114–122
51–55	0.41	0.67	0.76	123–131
56–60	—	0.58	0.71	132–140
61–65	—	0.47	0.65	141–149
66–70	—	0.33	0.58	150–158
71–75	—	—	0.50	159–167
76–80	—	—	0.41	168–176
81–85	—	—	0.29	177–185

135

AP Systems® YC600 Micro Inverters (usa.apsystems.com)

Example Sys. #1

APsystems YC600 Microinverter Datasheet



INPUT DATA (DC)

Module Compatibility	60 & 72 Cell PV Modules
MPPT Voltage Range	22V-48V
Operation Voltage Range	16V-55V
Maximum Input Voltage	60V
Maximum Input Current	12A x 2
Maximum Total PV Array Short Circuit Current	16A

OUTPUT DATA (AC)

	240V	208V
Maximum Continuous Output Power	548VA	548VA
Peak Output Power	600VA	600VA
Nominal Output Voltage	240V	208V
Nominal Output Current	2.28A	2.63A
Nominal Output Frequency	60Hz	60Hz
Adjustable Output Voltage Range	211-264V	183-229V
Adjustable Output Frequency Range	59.3 - 60.5Hz	59.3 - 60.5Hz
Power Factor (Adjustable)	0.8 leading...0.8 lagging	0.8 leading...0.8 lagging
Total Harmonic Distortion	<3%	<3%
Maximum Units per Branch	7 (14 PV modules)	6 (12 PV modules)

EFFICIENCY

Peak Efficiency	96.7%
CEC Weighted Efficiency	96.5%
Nominal MPPT Efficiency	99.5%
Night Power Consumption	60mW

MECHANICAL DATA

Operating Ambient Temperature Range	-40°F to +149°F (-40°C to +65°C)
Storage Temperature Range	-40°F to +185°F (-40°C to +85°C)
Dimensions (WxHxD) inches	10.24" x 7.4" x 1.24"
Dimensions (WxHxD) mm	260mm x 188mm x 31.5mm
Weight	5.7 lbs (2.6kg)
AC BUS Maximum Current	20A
Connector Type	MC4 Type
Enclosure Rating	NEMA 6 (IP67)
Cooling	Natural Convection - No Fans

FEATURES & COMPLIANCE

Communication	Wireless Zigbee
Transformer Design	High Frequency Transformers, Galvanic Isolation
Monitoring	Via EMA™ Online Portal
Emissions & Immunity (EMC) Compliance	FCC PART 15, ANSI C63.4, ICES-003
Safety & Grid Connection Compliance	UL1741, UL1741 SA, IEEE1547, CSA C22.2 No.107-01, NEC 2017 690.12, 690.11, CA Rule 21

136

Conductor And OCPD Sizing

Example Sys. #1

1. Max current
NEC 690.8(A)(3)

2. Breaker or fuse rating, and wire size
NEC 690.8(B) and 690.9(B)

AC Circuit Wiring Between AC combiner Panel and Service	(inverters combined max output amps)	(inverters max output × 125%)
	2.28 amps × 19 micro inverters →	43.3A x 1.25= 54A A

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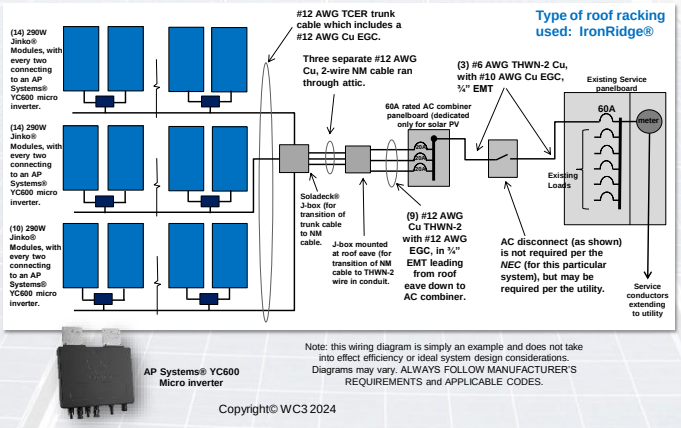
137

Example System (for an AP Systems® YC600 micro inverter system)

Example Sys. #1



Note: this wiring diagram is simply an example and does not take into effect efficiency or ideal system design considerations. Diagrams may vary. ALWAYS FOLLOW MANUFACTURER'S REQUIREMENTS and APPLICABLE CODES.

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138

Jinko® solar PV module specs (jinkosolar.com)

Example Sys. #1

139

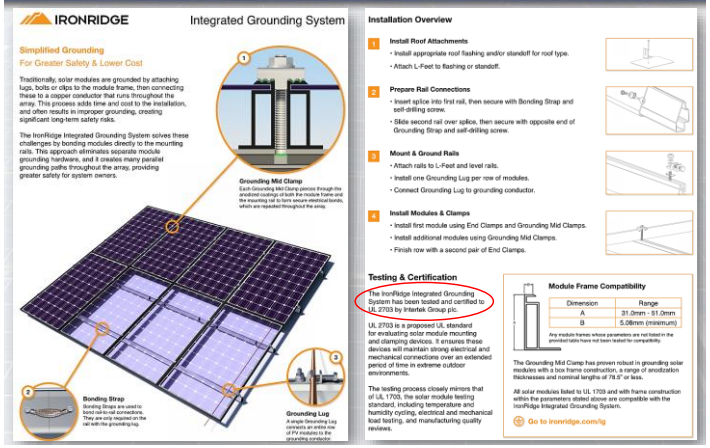
Jinko® UL 1703 Certification (jinkosolar.com)

Example Sys. #1

140

IronRidge® Racking Specs (Ironridge.com)

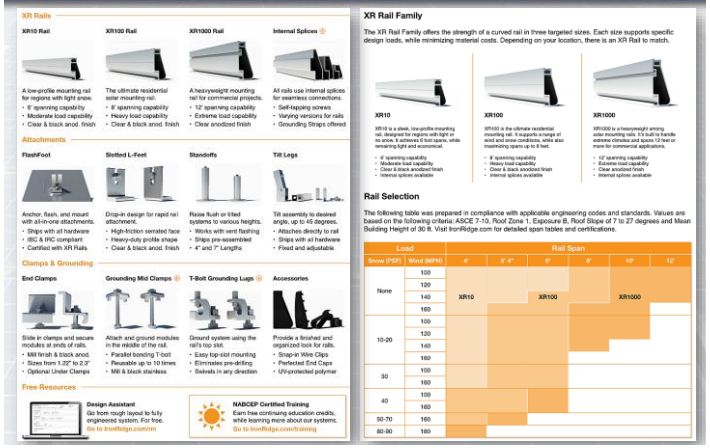
Example Sys. #1



141

IronRidge® Racking Specs (Ironridge.com)

Example Sys. #1



142

Signage

Example Sys. #1

All signage must be permanently attached and be able to withstand the environment they are installed. Signage also cannot be hand-written. *NEC* 110.21(B).

Parallel Generation On Site. Second Source is Solar PV

A sign is required at the service panel stating that the home has a solar PV system as an additional power source. *NEC* 705.10. Wording could vary.

Warning, ~~Inverter~~ Power Source Output Connection, Do Not Relocate This Overcurrent Device

This sign is required to be located next to the PV backfed breaker(s) **ONLY IF** the 120% allowance of *NEC* 705.12(B)(3)(2) is being utilized.

PV System:
AC Current = 43A
AC Volts = 240V

This sign is required to be located at the backfed panelboard. *NEC* 690.54.

SOLAR PV SYSTEM EQUIPPED WITH RAPID SHUTDOWN

TURN RAPID SHUTDOWN SWITCH TO THE "OFF" POSITION TO SHUTDOWN PV SYSTEM AND REDUCE SHOCK HAZARD IN ARRAY

This sign to be located on the outside of, and within 3' of the service equipment. *NEC* 690.56(C).

RAPID SHUTDOWN SWITCH FOR SOLAR PV SYSTEM

This sign must be reflective and is required to be located next to the disconnect switch which activates rapid shutdown. *NEC* 690.56(C)(2)
(for this system, it could be at any outdoor AC breaker or AC disconnect that isolates the micro inverters from the utility grid when such breaker or disconnect is shut off)

WARNING ELECTRIC SHOCK HAZARD TERMINALS ON THE LINE AND LOAD SIDES MAY BE ENERGIZED IN THE OPEN POSITION.

This sign is required at disconnects where terminals can be energized even when the disconnect is shut off. *NEC* 690.13(B).

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143

AC disconnects

Here is an example of an AC disconnect switch (used for a PV system) that would require the following sign:

WARNING ELECTRIC SHOCK HAZARD TERMINALS ON THE LINE AND LOAD SIDES MAY BE ENERGIZED IN THE OPEN POSITION.

NOTE: It's STRONGLY recommended that only AC disconnects with dead-fronts be used for a PV system!

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144

Plan Review Example System #2

Enphase® IQ7+™ Micro Inverter System

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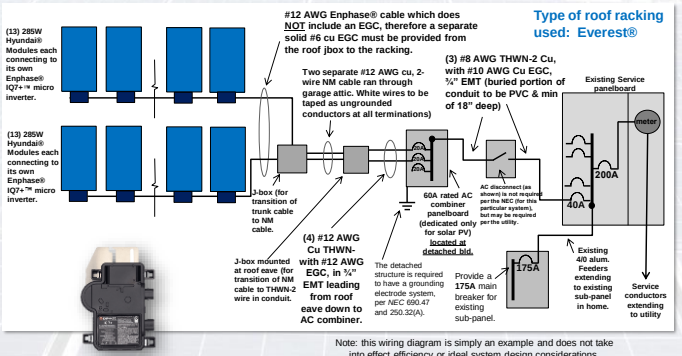
145

Example System (for an Enphase® IQ7+™ micro inverter system)

Example Sys. #2



Enphase® IQ7+™ Micro inverter

Note: this wiring diagram is simply an example and does not take into effect efficiency or ideal system design considerations. Diagrams may vary. ALWAYS FOLLOW MANUFACTURER'S REQUIREMENTS and APPLICABLE CODES.

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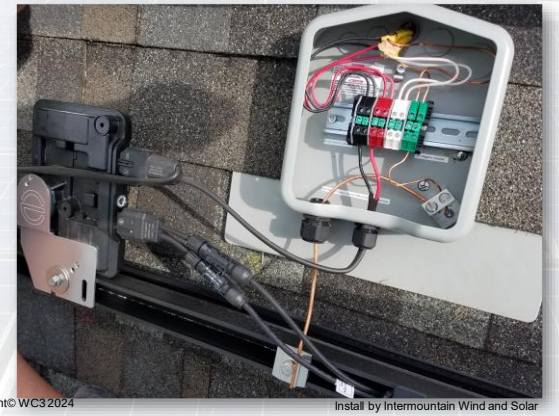
146

Enphase® IQ6™ Micro Inverters

Example Sys. #2



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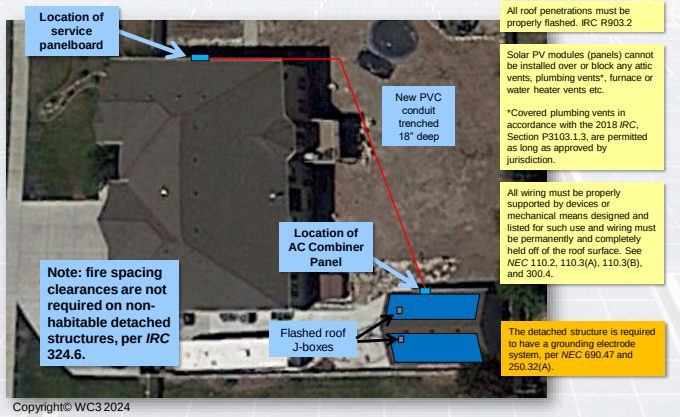
Install by Intermountain Wind and Solar

147

Site plan

Example Sys. #2



All roof penetrations must be properly flashed. IRC R903.2

Solar PV modules (panels) cannot be installed over or block any attic vents, plumbing vents*, furnace or water heater vents etc.

*Covered plumbing vents in accordance with the 2018 *IRC*, Section P3103.1.3, are permitted as long as approved by jurisdiction.

All wiring must be properly supported by devices or mechanical means designed and listed for such use and wiring must be permanently and completely held off of the roof surface. See *NEC* 110.2, 110.3(A), 110.3(B), and 300.4.

The detached structure is required to have a grounding electrode system, per *NEC* 690.47 and 250.32(A).

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148

Photo of Service Panel

Example Sys. #2

Typically, photos of the service panel label are needed in order to show the rating of the service (and rating of breaker slots).

Also, a clear photo showing the rating of the main service breaker(s) is usually required (in order to determine load-side connection rules).

For this example, we are assuming that the service panel is rated for **200A** since the main service breaker is rated **200A**.

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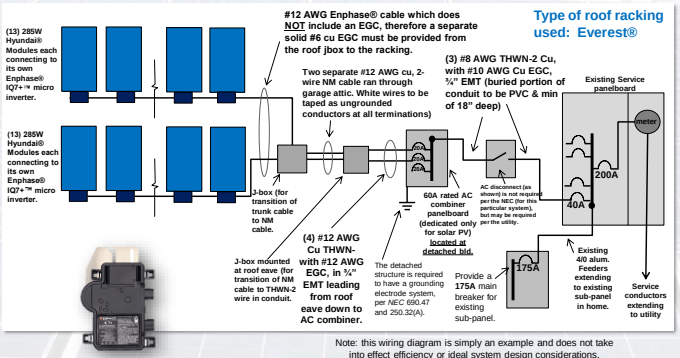
149

Example System (for an Enphase® IQ7+™ micro inverter system)

Example Sys. #2



Note: this wiring diagram is simply an example and does not take into effect efficiency or ideal system design considerations. Diagrams may vary. ALWAYS FOLLOW MANUFACTURER'S REQUIREMENTS and APPLICABLE CODES.

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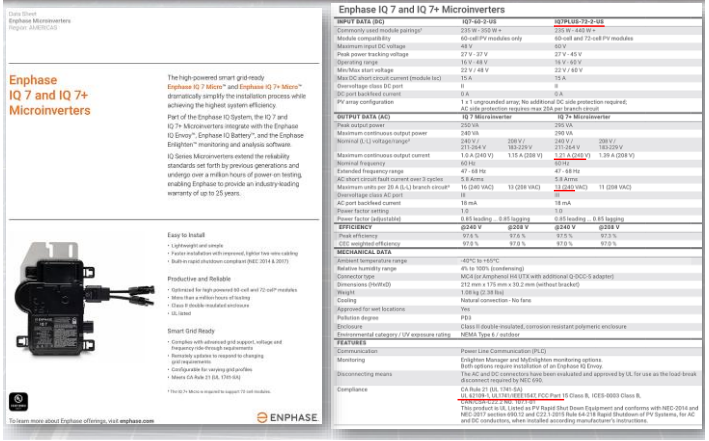
150

Enphase® IQ7+™ Specs

Example Sys. #2



Enphase IQ 7 and IQ 7+ Microinverters

INPUT DATA (DC)	IQ7-60-2-US	IQ7PLUS-72-2-US
Commonly used module pairings¹	235 W - 350 W +	235 W - 440 W +
Module compatibility	60-cell PV modules only	60-cell and 72-cell PV modules
Maximum input DC voltage	48 V	60 V
Peak power tracking voltage	27 V - 37 V	27 V - 45 V
Operating range	16 V - 48 V	16 V - 60 V
Min/Max start voltage	22 V / 48 V	22 V / 60 V
Max DC short circuit current (module Isc)	15 A	15 A
Overvoltage class DC port	II	II
DC port backfeed current	0 A	0 A
PV array configuration	1 x 1 ungrounded array; No additional DC side protection required; AC side protection requires max 20A per branch circuit	

OUTPUT DATA (AC)	IQ 7 Microinverter	IQ 7+ Microinverter
Peak output power	250 VA	295 VA
Maximum continuous output power	240 VA	290 VA
Nominal (L-L) voltage/range²	240 V / 211-264 V / 208 V / 183-229 V	240 V / 211-264 V / 208 V / 183-229 V
Maximum continuous output current	1.0 A (240 V) / 1.15 A (208 V)	1.21 A (240 V) / 1.39 A (208 V)
Nominal frequency	60 Hz	60 Hz
Extended frequency range	47 - 68 Hz	47 - 68 Hz
AC short circuit fault current over 3 cycles	5.8 Arms	5.8 Arms
Maximum units per 20 A (L-L) branch circuit³	16 (240 VAC) / 13 (208 VAC)	13 (240 VAC) / 11 (208 VAC)
Overvoltage class AC port	III	III
AC port backfeed current	18 mA	18 mA
Power factor setting	1.0	1.0
Power factor (adjustable)	0.85 leading ... 0.85 lagging	0.85 leading ... 0.85 lagging

EFFICIENCY	@240 V	@208 V	@240 V	@208 V
Peak efficiency	97.6 %	97.6 %	97.6 %	97.6 %
CEC weighted efficiency	97.0 %	97.0 %	97.0 %	97.0 %

MECHANICAL DATA	
Ambient temperature range	-40°C to +65°C
Relative humidity range	4% to 100% (condensing)
Connector type	MC4 (or Amphenol H4 UTX with additional Q-DCC-5 adapter)
Dimensions (HxWxD)	212 mm x 175 mm x 30.2 mm (without bracket)
Weight	1.08 kg (2.38 lbs)
Cooling	Natural convection - No fans
Approved for wet locations	Yes
Pollution degree	PD3
Enclosure	Class II double-insulated, corrosion resistant polymeric enclosure
Environmental category / UV exposure rating	NEMA Type 6 / outdoor

FEATURES	
Communication	Power Line Communication (PLC)
Monitoring	Enlighten Manager and MyEnlighten monitoring options. Both options require installation of an Enphase IQ Envoy.
Disconnecting means	The AC and DC connectors have been evaluated and approved by UL for use as the load-break disconnect required by NEC 690.
Compliance	CA Rule 21 (UL 1741-SA) UL 62109-1, UL1741/IEEE1547, FCC Part 15 Class B, ICES-0003 Class B, CAN/CSA-C22.2 NO. 107.1-01 This product is UL Listed as PV Rapid Shut Down Equipment and conforms with NEC 2014 and NEC 2017 section 690.12 and C22.1-2015 Rule 64-218 Rapid Shutdown of PV Systems, for AC and DC conductors, when installed according manufacturer's instructions.

151

Conductor Ampacity and OCPD Sizing

Example Sys. #2

1. Max current
NEC 690.8(A)(1)(c)

2. Breaker or fuse rating, and wire ampacity
NEC 690.8(B) and 690.9(B)

AC Circuit Wiring Between AC combiner Panel and Service	(inverters combined max output amps)	(inverters max output × 125%)
	1.21 amps × 26 micro inverters →	31.5A x 1.25= 39A A

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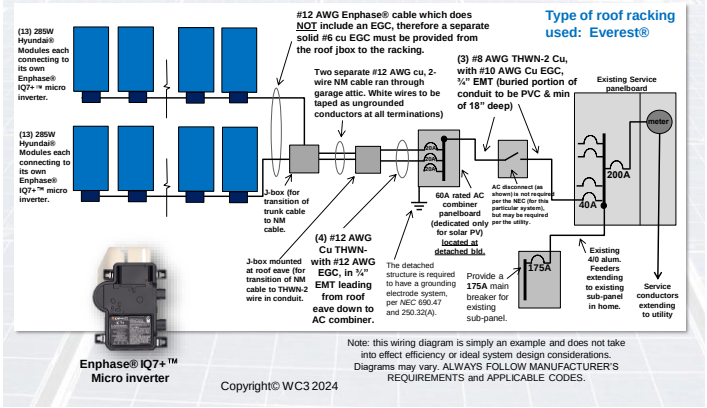
152

Example System (for an Enphase® IQ7+™ micro inverter system)

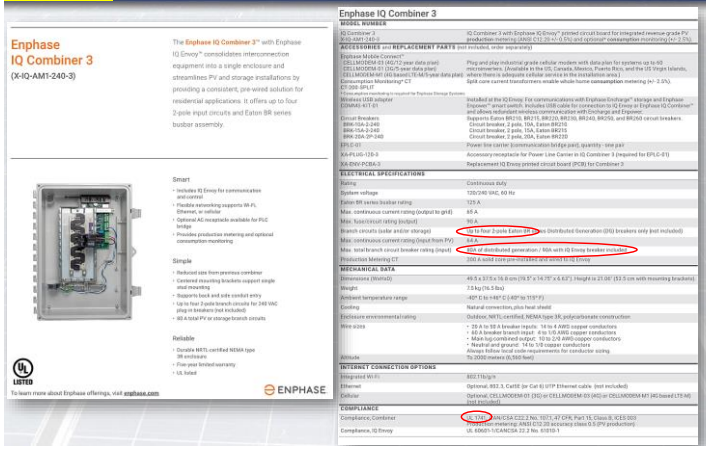
Example Sys. #2



153

Enphase® AC Combiner Panel (Enphase.com)

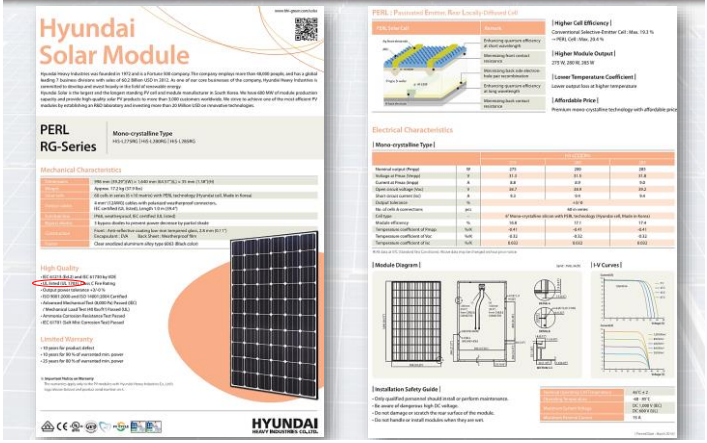
Example Sys. #2



154

Hyundai PV Module Specs (hhi-green.com/solar)

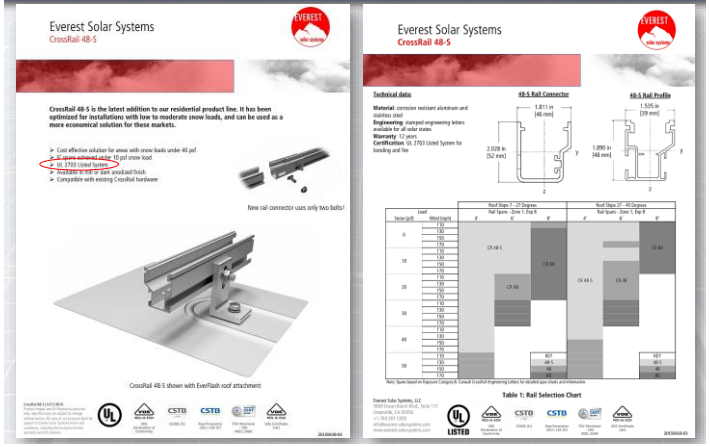
Example Sys. #2



155

Everest® Racking Specs (Everest-solarsystems.com)

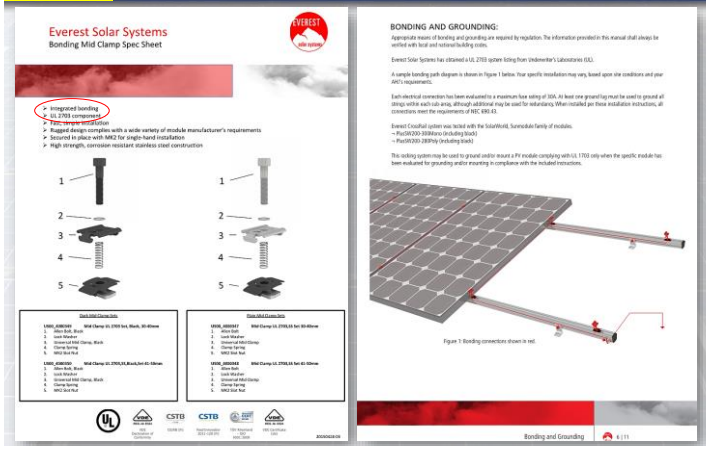
Example Sys. #2



156

Everest® Racking Specs (Everest-solarsystems.com)

Example Sys. #2



157

Signage

Example Sys. #2

All signage must be permanently attached and be able to withstand the environment they are installed. Signage also cannot be hand-written. *NEC* 110.21(B).

CAUTION: MULTIPLE SOURCES OF POWER

The above shown sign is required at the service disconnect. *NEC* 705.10.

WARNING: POWER SOURCE OUTPUT DO NOT RELOCATE THIS OVERCURRENT DEVICE.

This sign is required to be located next to the PV backfed breaker(s) **ONLY if** the 120% allowance of *NEC* 705.12(B)(3)(2) is being utilized.

PV System:
AC Current = 30A
AC Volts = 240V

This sign is required to be located at the backfed panelboard. *NEC* 690.54 (of the **2020** *NEC*).

SOLAR PV SYSTEM EQUIPPED WITH RAPID SHUTDOWN

TURN RAPID SHUTDOWN SWITCH TO THE "OFF" POSITION TO SHUTDOWN PV SYSTEM AND REDUCE SHOCK HAZARD IN ARRAY

This sign to be located on the outside of, and within 3' of the service equipment. *NEC* 690.56(C).

RAPID SHUTDOWN SWITCH FOR SOLAR PV SYSTEM

This sign must be reflective and is required to be located next to the disconnect switch which activates rapid shutdown. *NEC* 690.56(C)(2) **(for this system, it could be at any AC breaker or AC disconnect that isolates the micro inverters from the utility grid when such breaker or disconnect is shut off)**

WARNING ELECTRIC SHOCK HAZARD TERMINALS ON THE LINE AND LOAD SIDES MAY BE ENERGIZED IN THE OPEN POSITION.

This sign is required at disconnects where terminals can be energized even when the disconnect is shut off. *NEC* 690.13(B).

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158

Plan Review Example System #3

SMA® Sunny Boy™ String Inverter System

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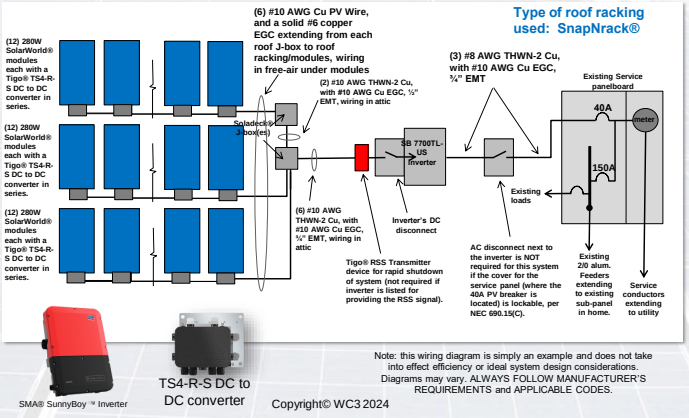
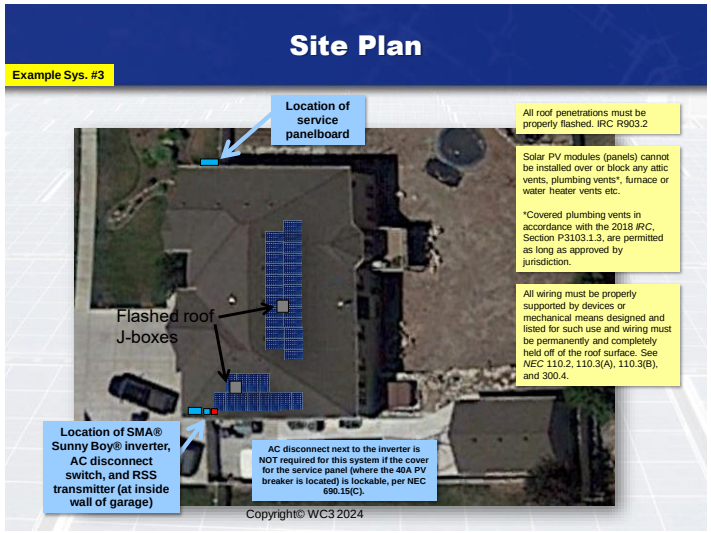
159

Example Single-Line Diagram (for an SMA® string inverter system)

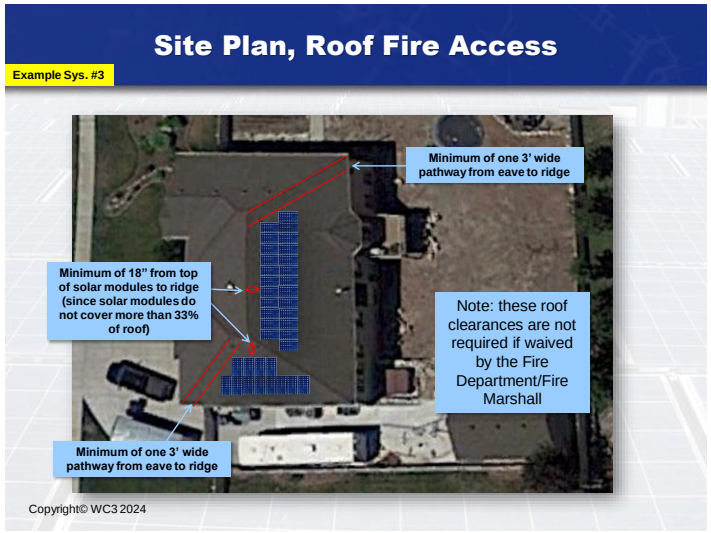
Example Sys. #3



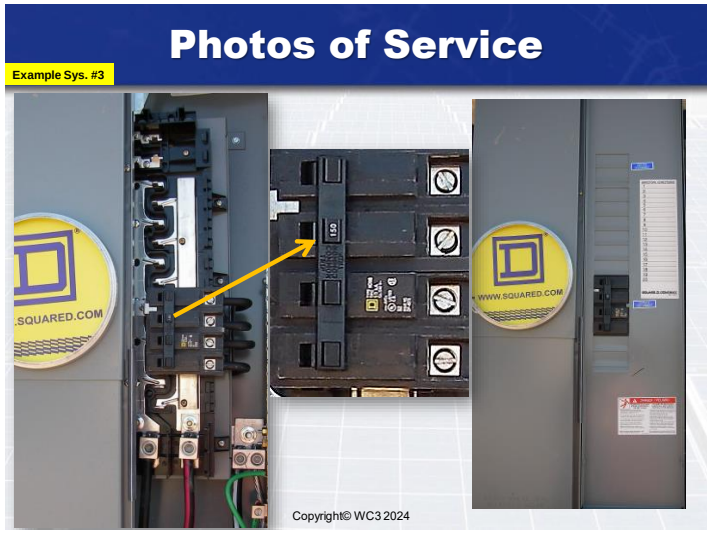
160



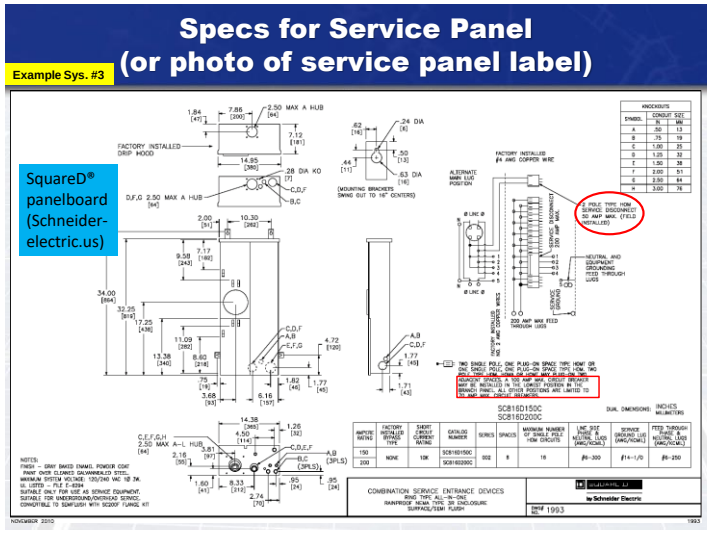
161



162



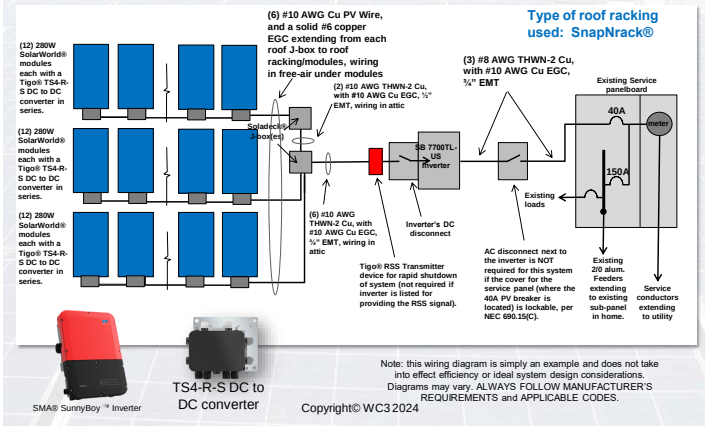
163



164

Example Single-Line Diagram (for an SMA® string inverter system)

Example Sys. #3



165

SMA® Spec Sheets (sma-America.com)

Example Sys. #3

166

SMA® Spec Sheets (sma-America.com)

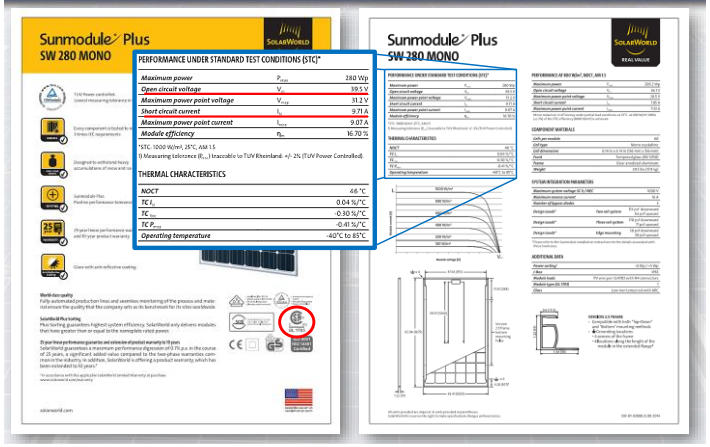
Example Sys. #3

Technical data	Sunny Boy 6.0-US		Sunny Boy 7.0-US		Sunny Boy 7.7-US	
	208 V	240 V	208 V	240 V	208 V	240 V
Input (DC)						
Max. PV power	9600 Wp		9940 Wp		10905 Wp	
Max. DC Voltage	600 V					
Rated MPP Voltage range	220 – 480 V		245 – 480 V		270 – 480 V	
MPPT operating voltage range	100 – 550 V					
Min. DC voltage / start voltage	100 V / 125 V					
Max. operating input current per MPPT	10 A					
Max. short circuit current per MPPT	18 A					
Number of MPPT tracker / string per MPPT tracker	3 / 1					
Output (AC)						
AC nominal power	5200 W	6000 W	6660 W	7000 W	6660 W	7680 W
Max. AC apparent power	5200 VA	6000 VA	6660 VA	7000 VA	6660 VA	7680 VA
Nominal voltage / adjustable	208 V / ●	240 V / ●	208 V / ●	240 V / ●	208 V / ●	240 V / ●
AC voltage range	183 – 229 V	211 – 264 V	183 – 229 V	211 – 264 V	183 – 229 V	211 – 264 V
AC grid frequency	60 Hz / 50 Hz					
Max. output current	25.0 A	25.0 A	32.0 A	29.2 A	32.0 A	32.0 A
Power factor (cos φ)	1					
Output phases / line connections	1 / 2					
Harmonics	< 4 %					
Efficiency						
Max. efficiency	97.3 %	97.7 %	97.3 %	97.9 %	97.3 %	97.5 %
CEC efficiency	96.7 %	96.9 %	96.4 %	96.8 %	96.4 %	96.8 %
Protection devices						
DC disconnect device / DC reverse polarity protection	● / ●					
Ground fault monitoring / Grid monitoring	●					
AC short circuit protection	●					
All-pole sensitive residual current monitoring unit (RCMU)	●					
Arc fault circuit interrupter (AFCI)	●					
Protection class / overvoltage category	I / IV					
General data						
Dimensions (W / H / D) in mm (in)	535 x 730 x 198 (21.1 x 28.5 x 7.8)					
Packaging Dimensions (W / H / D) in mm (in)	600 x 800 x 300 (23.6 x 31.5 x 11.8)					
Weight / packaging weight	26 kg (57 lb) / 30 kg (66 lb)					
Temperature range: operating / non-operating	-25°C ...+60°C / -40°C ...+60°C					
Environmental protection rating	NEMA 3R					
Noise emission (typical)	39 dB(A)		45 dB(A)			
Internal power consumption at night	< 5 W					

167

SolarWorld® PV Module Specs (solarworld-usa.com)

Example Sys. #3



168

Cold Temperature DC Voltage

Example Sys. #3

Maximum system DC voltage calculation:

Open Circuit Voltage (Voc) of modules= 39.5V DC (at 25˚C or 77˚F)

39.5V × 12 modules= **474V** (at 77˚F)

If we use -20˚C for our coldest temperature (which is noted in the ASHRAE Fundamentals Handbook for the SLC valley):

The difference in temperature drop from 25˚C to -20˚C is **45˚C**.

Per the modules specs, the voltage of the modules increases by .30% for every 1˚C.

Take 45˚C × .30 = a voltage increase of 13.5% at -20˚C.

474V × 1.135= a cold temperature voltage of **538V**.

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169

Conductor Ampacity and OCPD Sizing

Example Sys. #3

	1. Max current *NEC* 690.8(A)(1)(a-c)	2. Breaker or fuse rating, and wire ampacity *NEC* 690.8(B) and 690.9(B)
String circuit (source circuit)	(string Isc x 125%) **9.71** x 1.25= **12.14** A →	(string max current x 125% again) **12.14** x 1.25= **15.2** A
~~PV output Circuit~~ (circuit between DC combiner box and inverter)	(each strings' max DC current combined together) ____ x __ **(# of strings)**= ____ A →	(Total combined strings' max current x 125%) ____ x 1.25= ____ A
Inverter AC Output Circuit	(inverter max output) **32** amps →	(inverter max output x 125%) **32** x 1.25= **40** A

Use the max amps in this column when starting the adjustment of wires for temp. and conduit fill. Take the larger of either the final adjusted ampacity from this column or the final amps in column 2 to size the conductors, *NEC* 690.8(B)(2).

If no deration or adjustment of wires is needed then use this column to size wire ampacity. Always use this column to size the breaker or fuses (use next size up breaker or fuse if between ratings).

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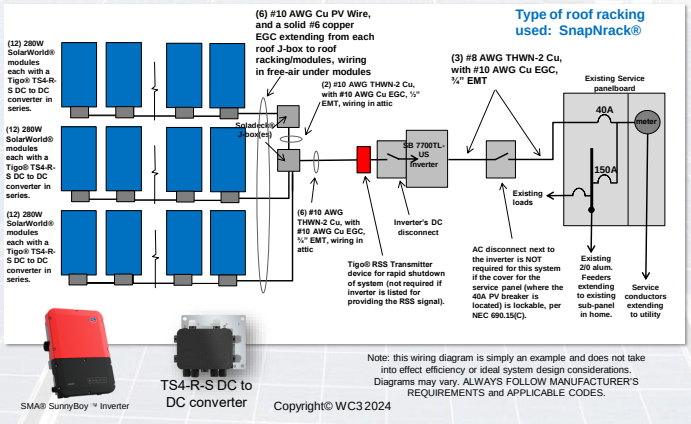
170

Example Single-Line Diagram (for an SMA® string inverter system)

Example Sys. #3



Note: this wiring diagram is simply an example and does not take into effect efficiency or ideal system design considerations. Diagrams may vary. ALWAYS FOLLOW MANUFACTURER'S REQUIREMENTS and APPLICABLE CODES.

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171

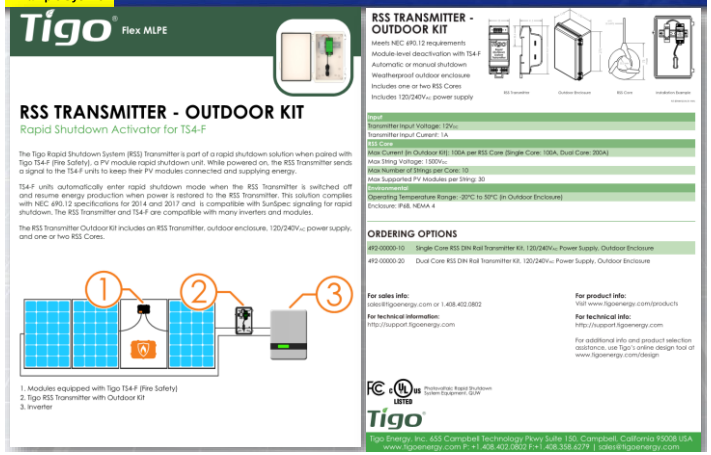
SMA® Rapid Shutdown Specs for Tigo® Optimizers (sma-America.com)

Example Sys. #3

172

SMA® Rapid Shutdown Specs for Tigo® Optimizers (sma-America.com)

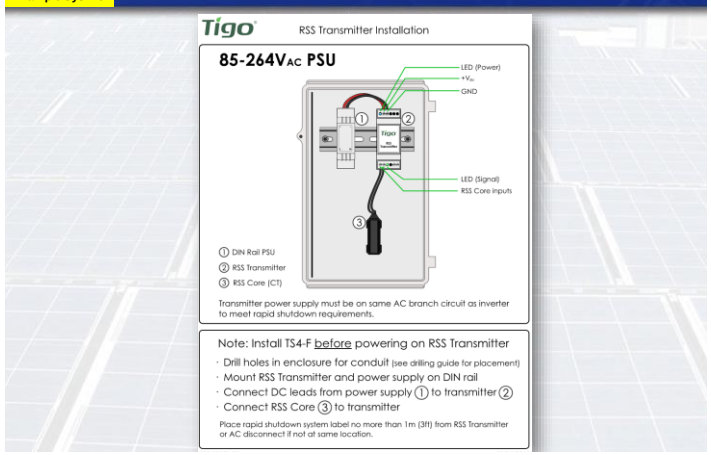
Example Sys. #3



173

SMA® Rapid Shutdown Specs for Tigo® Optimizers (sma-America.com)

Example Sys. #3



174

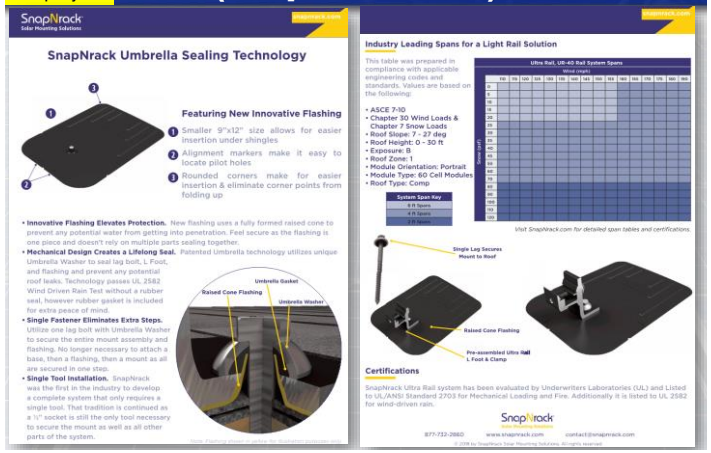
SnapNrack® Specs (snapnrack.com)

Example Sys. #3

175

SnapNrack® Wind Loading Tables (snapnrack.com)

Example Sys. #3



176

Signage

Example Sys. #3

All signage must be permanently attached and be able to withstand the environment they are installed. Signage also cannot be hand-written. ***NEC*** **110.21(B).**

CAUTION: MULTIPLE SOURCES OF POWER

The above shown sign is required at the service disconnect. *NEC* 705.10.

PV System:
AC Current = 32A
AC Volts = 240V

This sign is required to be located at the backfed panelboard. *NEC* 690.54 (per the **2020** ***NEC***).

Maximum DC Voltage = 600V

This sign is required to be mounted on the **string** inverter. *NEC* 690.54

WARNING: POWER SOURCE OUTPUT DO NOT RELOCATE THIS OVERCURRENT DEVICE.

This sign is required to be located next to the AC PV backfed breaker(s) **ONLY if** the 120% allowance of *NEC* 705.12(B)(3)(2) is being utilized.

SOLAR PV SYSTEM EQUIPPED WITH RAPID SHUTDOWN

TURN RAPID SHUTDOWN SWITCH TO THE "OFF" POSITION TO SHUTDOWN PV SYSTEM AND REDUCE SHOCK HAZARD IN ARRAY

This sign to be located on the outside of, and within 3' of the service equipment. *NEC* 690.56(C).

RAPID SHUTDOWN SWITCH FOR SOLAR PV SYSTEM

This sign must be reflective and is required to be located next to the disconnect switch which activates rapid shutdown. *NEC* 690.56(C)(2)
(for this system, it would be the 40A solar PV breaker located in the service meter panelboard)

PHOTOVOLTAIC POWER SOURCE

This sign is to be located on the outside of any conduits, enclosures, or MC cable that contain **DC** circuits. The markings shall **be reflective** and be provided at every enclosure, every 10' along conduit or MC cable, and at each side of where the conduit or cable passes through a wall, floor, or any other partition. The markings shall be permanently affixed and visible after installation. *NEC* 690.31(D)(2)

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177

Plan Review Example System #4

SolarEdge® HDwave™ String Inverter System – Ground Mounted PV

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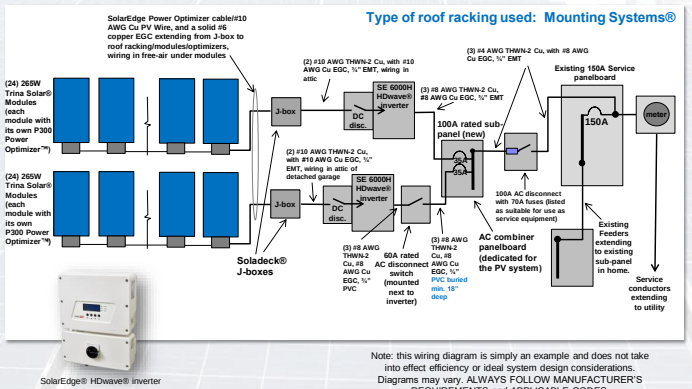
178

A SolarEdge® system (with two HDwave® SolarEdge® inverters)

Example Sys. #4



Note: this wiring diagram is simply an example and does not take into effect efficiency or ideal system design considerations. Diagrams may vary. ALWAYS FOLLOW MANUFACTURER'S REQUIREMENTS and APPLICABLE CODES.

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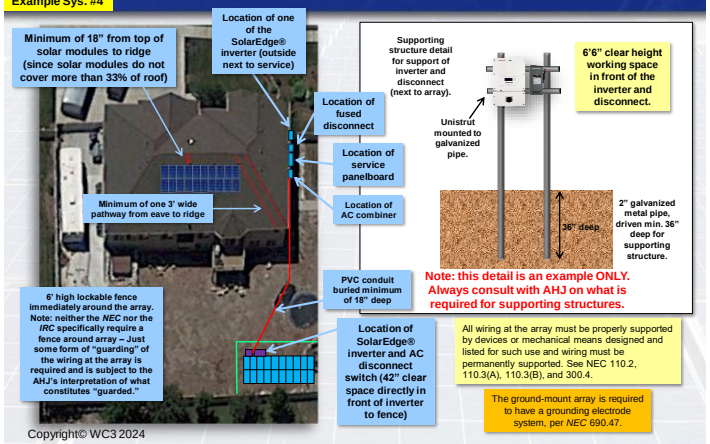
179

Site plan

Example Sys. #4



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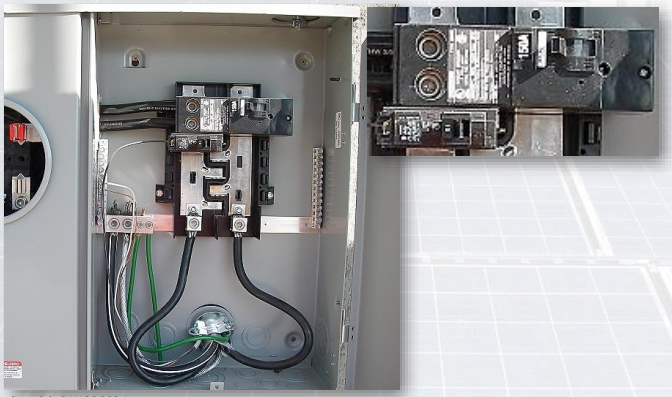
180

Photos of Service Panel

Example Sys. #4



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181

SIEMENS

Rainproof Combination Metering

Catalog Number
MC0816B1200TH

Enclosure
Type 3R

RATING
200 AMPS MAX.
120/240 VOLTS AC, 1 PHASE, 3 WIRE
208Y/120 VOLTS AC, 1 PHASE, 3 WIRE, WHEN 5TH JAW IS INSTALLED.
(DERIVED FROM 3 PHASE - 4 WIRE SYSTEM)

METER SOCKET RATING
200 AMPS CONTINUOUS

SUITABLE ONLY FOR USE AS SERVICE EQUIPMENT.

FOR OVERHEAD OR UNDERGROUND SERVICE
USE 60/75° COPPER OR ALUMINUM CONDUCTOR IN TERMINALS A1, B1, N1, N2, N3, G1, A2 AND B2.

Terminal	Wire Size	Torque
A1, B1	350kcmil - #6	275 lb-in
N1	#2 - #3	50 lb-in
	#4 - #6	45 lb-in
	#8	40 lb-in
	#10 - #14	35 lb-in
N2	250kcmil - #6	275 lb-in
A2, B2, G1	250kcmil - #6	275 lb-in
G2	1/0 - #14	120 lb-in
Branch Breaker Terminals	See Markings on Breaker	
Neutral Bar	#10 - #14 CU	20 lb-in
	#10 - #12 AL	20 lb-in
	#8	25 lb-in
	#6 - #4	35 lb-in
Ground Conductors	(1) or (3) #14 AWG	20 lb-in
Only	(2) #12-#10 AWG	20 lb-in

GENERAL INFORMATION
REMOVE TWISTOUTS FROM DEADFRONT ONLY WHERE BREAKERS WILL BE INSTALLED. ALL OPENINGS MUST BE FILLED WITH BREAKERS OR FILLER PLATES.

CIRCUIT BREAKERS OVERLOAD TRIP POSITION IS INDICATED BY HANDLE POSITION MIDWAY BETWEEN ON AND OFF. TO RESET, MOVE HANDLE TO OFF POSITION THEN TURN ON.

FOR INSTALLATION IN ACCORDANCE WITH ALL LOCAL ELECTRICAL CODES AND/OR THE NATIONAL ELECTRICAL CODES.

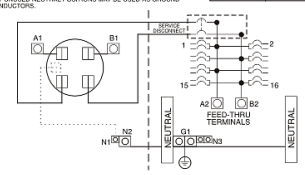
SUM OF QF, QT, QPF, QE, QAF, QG, QW BREAKERS NOT TO EXCEED 80 AMPS PER STAB.

ANY UNUSED NEUTRAL POSITIONS MAY BE USED AS GROUND CONDUCTORS.

ACCESSORIES
FILLER PLATE - CAT. NO. QF3
5th JAW ACCESSORY - CAT. NO. MC5J
LAY-IN LUG NEUTRAL KIT - CAT. NO. LLK1

IF HUB IS REQUIRED, THE CATALOG NUMBERS LISTED BELOW MAY BE USED ON THIS ENCLOSURE

TRADE SIZE (IN.)	CATALOG NUMBER
1-1/4"	RX125
1-1/2"	RX150
2"	RX200
2-1/2"	RX250

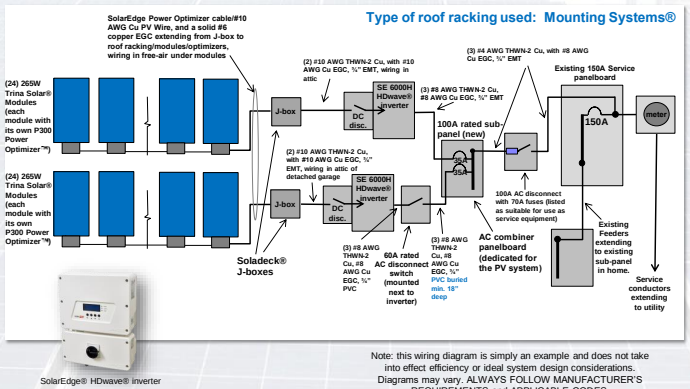


Specs for the Siemens® MC0816B1200TH service panelboard (Siemens.com)

182

A SolarEdge® system (with two HDwave® SolarEdge® inverters)

Example Sys. #4



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183

Inverter Specs (solaredge.com)

Example Sys. #4

Single Phase Inverter with HD-Wave Technology for North America

SE3000H-US / SE3800H-US / SE5000H-US / SE6000H-US / SE7600H-US / SE10000H-US / SE11400H-US

Optimized installation with HD-Wave technology

- Specifically designed to work with power optimizers
- Record-breaking 99% weighted efficiency
- Quick and easy inverter commissioning directly from a smartphone using the SolarEdge SetApp
- Fixed voltage inverter for longer strings
- Integrated arc fault protection and rapid shutdown for NEC 2014 and 2017, per article 690.11 and 690.12
- UL1741 SA certified, for CPUC Rule 21
- Small, lightweight, and easy to install on pole or indoors
- Built-in module-level monitoring
- Optional: Faster installations with built-in metering (1% accuracy) and production metering (0.5% accuracy, ANSI C12.20)

solaredge.com

Single Phase Inverter with HD-Wave Technology for North America

SE3000H-US / SE3800H-US / SE5000H-US / SE6000H-US/ SE7600H-US / SE10000H-US / SE11400H-US

MODEL NUMBER	SE3000H-US	SE3800H-US	SE5000H-US	SE6000H-US	SE7600H-US	SE10000H-US	SE11400H-US
APPLICABLE TO INVERTERS WITH PART NUMBER	SE3000H-XXXXXBX4						
OUTPUT							
Rated AC Power Output	3000	3800 @ 240V 3300 @ 208V	5000	6000 @ 240V 5999 @ 208V	7600	10000	11400 @ 240V 10000 @ 208V
Maximum AC Power Output	3000	3800 @ 240V 3300 @ 208V	5000	6000 @ 240V 5999 @ 208V	7600	10000	11400 @ 240V 10000 @ 208V
AC Output Voltage Min.-Nom.-Max. (183 - 208 - 229)	✓	✓	✓	✓	✓	✓	✓
AC Output Voltage Min.-Nom.-Max. (211 - 240 - 264)		✓		✓		✓	✓
AC Frequency (Nominal)				59.3 - 60 - 60.5[1]			
Maximum Continuous Output Current @240V	12.5	16	21	25	32	42	47.5
Maximum Continuous Output Current @208V		16		24			48.5
Power Factor				1 - Adjustable -0.85 to 0.85			
GFDI Threshold				1			
Utility Monitoring, Islanding Protection, Country Configurable Thresholds				Yes			
INPUT							
Maximum DC Power @240V	4650	5900	7750	9300	11800	15500	17650
Maximum DC Power @208V	-	5100	-	7750	-	-	15500
Transformer-less, Ungrounded				Yes			
Maximum Input Voltage				480			
Nominal DC Input Voltage		380			400		
Maximum Input Current @240V[2]	8.5	10.5	13.5	16.5	20	27	30.5
Maximum Input Current @208V[2]	-	9	-	13.5	-	-	27
Max. Input Short Circuit Current				45			
Reverse-Polarity Protection				Yes			
Ground-Fault Isolation Detection				600kΩ Sensitivity			
Maximum Inverter Efficiency	99			99.2			
CEC Weighted Efficiency				99			99 @ 240V 98.5 @ 208V
Nighttime Power Consumption				< 2.5			

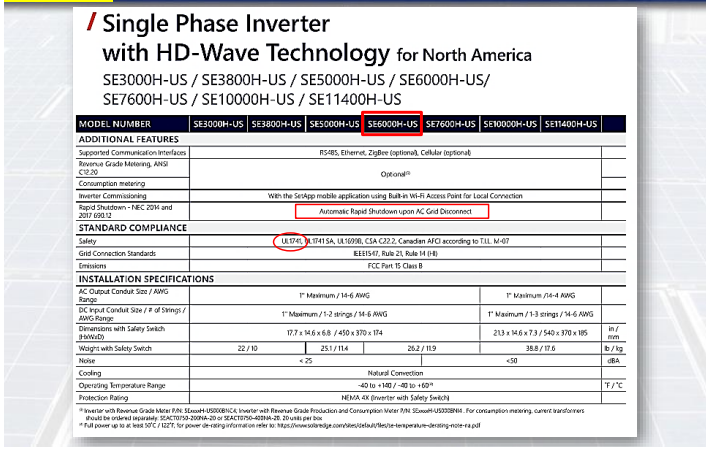
[1] For other regional settings please contact SolarEdge support
[2] A higher current source may be used, the inverter will limit its input current to the values stated

solaredge

184

Inverter Specs (solaredge.com)

Example Sys. #4



Single Phase Inverter
with HD-Wave Technology for North America
SE3000H-US / SE3800H-US / SE5000H-US / SE6000H-US/
SE7600H-US / SE10000H-US / SE11400H-US

MODEL NUMBER	SE3000H-US	SE3800H-US	SE5000H-US	SE6000H-US	SE7600H-US	SE10000H-US	SE11400H-US
ADDITIONAL FEATURES							
Supported Communication Interfaces	RS485, Ethernet, ZigBee (optional), Cellular (optional)						
Revenue Grade Metering, ANSI C12.20	Optional[2]						
Consumption metering							
Inverter Commissioning	With the SetApp mobile application using Built-in Wi-Fi Access Point for Local Connection						
Rapid Shutdown - NEC 2014 and 2017 690.12	Automatic Rapid Shutdown upon AC Grid Disconnect						
STANDARD COMPLIANCE							
Safety	UL1741, UL1741 SA, UL1699B, CSA C22.2, Canadian AFCI according to T.I.L. M-07						
Grid Connection Standards	IEEE1547, Rule 21, Rule 14 (HI)						
Emissions	FCC Part 15 Class B						
INSTALLATION SPECIFICATIONS							
AC Output Conduit Size / AWG Range	1" Maximum / 14-6 AWG				1" Maximum / 14-4 AWG		
DC Input Conduit Size / # of Strings / AWG Range	1" Maximum / 1-2 strings / 14-6 AWG				1" Maximum / 1-3 strings / 14-6 AWG		
Dimensions with Safety Switch (HxWxD)	17.7 x 14.6 x 6.8 / 450 x 370 x 174				21.3 x 14.6 x 7.3 / 540 x 370 x 185		in / mm
Weight with Safety Switch	22 / 10	25.1 / 11.4	26.2 / 11.9		38.8 / 17.6		lb / kg
Noise	< 25				<50		dBA
Cooling	Natural Convection						
Operating Temperature Range	-40 to +140 / -40 to +60[3]						°F / °C
Protection Rating	NEMA 4X (Inverter with Safety Switch)						

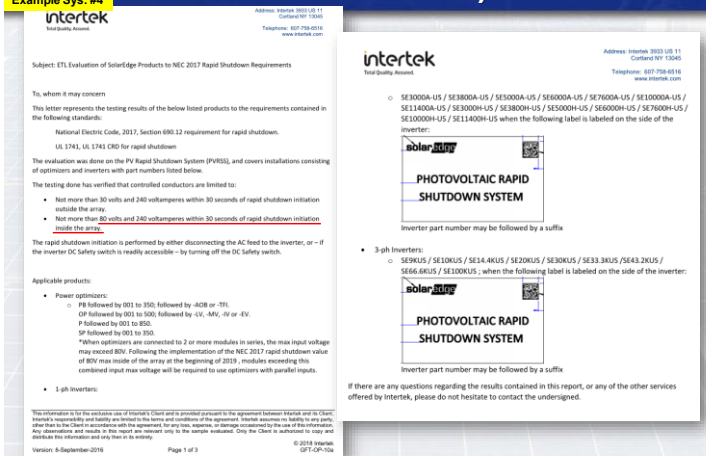
[1] Inverter with Revenue Grade Meter P/N: SExxxH-US000BNC4; Inverter with Revenue Grade Production and Consumption Meter P/N: SExxxH-US000BNI4 . For consumption metering, current transformers should be ordered separately: SCACT0750-200NA-20 or SCACT0750-400NA-20. 20 units per box

[2] Full power up to at least 50°C / 122°F, for power de-rating information refer to: https://www.solaredge.com/sites/default/files/se-temperature-derating-note-na.pdf

185

Inverter Certification (SolarEdge.com and Intertek.com)

Example Sys. #4



Subject: ETL Evaluation of SolarEdge Products to NEC 2017 Rapid Shutdown Requirements

To, whom it may concern

This letter represents the testing results of the below listed products to the requirements contained in the following standards:

National Electric Code, 2017, Section 690.12 requirement for rapid shutdown.

UL 1741, UL 1741 CRD for rapid shutdown

The evaluation was done on the PV Rapid Shutdown System (PVRSS), and covers installations consisting of optimizers and inverters with part numbers listed below.

The testing done has verified that controlled conductors are limited to:

- Not more than 30 volts and 240 voltamperes within 30 seconds of rapid shutdown initiation outside the array.
- Not more than 80 volts and 240 voltamperes within 30 seconds of rapid shutdown initiation inside the array.

The rapid shutdown initiation is performed by either disconnecting the AC feed to the inverter, or – if the inverter DC Safety switch is readily accessible – by turning off the DC Safety switch.

Applicable products:

- Power optimizers:
  - P8 followed by 001 to 350; followed by -AOB or -TFI.
    OP followed by 001 to 500; followed by -LV, -MV, -IV or -EV.
    P followed by 001 to 850.
    SP followed by 001 to 350.
    *When optimizers are connected to 2 or more modules in series, the max input voltage may exceed 80V. Following the implementation of the NEC 2017 rapid shutdown value of 80V max inside of the array at the beginning of 2019 , modules exceeding this combined input max voltage will be required to use optimizers with parallel inputs.
- 1-ph inverters:

intertek

Address: Intertek 3933 US 11 Cortland NY 13045

Telephone: 607-758-6516

www.intertek.com

- SE3000A-US / SE3800A-US / SE5000A-US / SE6000A-US / SE7600A-US / SE10000A-US / SE11400A-US / SE3000H-US / SE3800H-US / SE5000H-US / SE6000H-US / SE7600H-US / SE10000H-US / SE11400H-US when the following label is labeled on the side of the inverter:

solaredge
PHOTOVOLTAIC RAPID SHUTDOWN SYSTEM

Inverter part number may be followed by a suffix

- 3-ph Inverters:
  - SE9KUS / SE10KUS / SE14.4KUS / SE20KUS / SE30KUS / SE33.3KUS /SE43.2KUS / SE66.6KUS / SE100KUS ; when the following label is labeled on the side of the inverter:

solaredge
PHOTOVOLTAIC RAPID SHUTDOWN SYSTEM

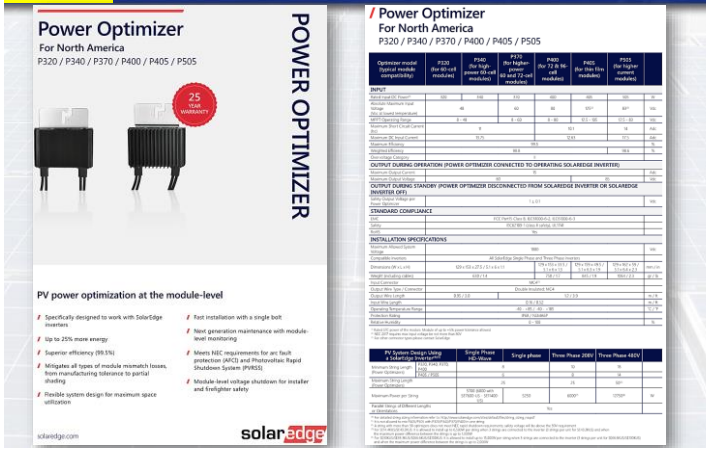
Inverter part number may be followed by a suffix

If there are any questions regarding the results contained in this report, or any of the other services offered by Intertek, please do not hesitate to contact the undersigned.

186

SolarEdge® Power Optimizer™ Specs (solaredge.com)

Example Sys. #4



Power Optimizer
For North America
P320 / P340 / P370 / P400 / P405 / P505

25 YEAR WARRANTY

POWER OPTIMIZER

PV power optimization at the module-level

- Specifically designed to work with SolarEdge inverters
- Up to 25% more energy
- Superior efficiency (99.5%)
- Mitigates all types of module mismatch losses, from manufacturing tolerance to partial shading
- Flexible system design for maximum space utilization
- Fast installation with a single bolt
- Next generation maintenance with module-level monitoring
- Meets NEC requirements for arc fault protection (AFCI) and Photovoltaic Rapid Shutdown System (PVRSS)
- Module-level voltage shutdown for installer and firefighter safety

solaredge.com

solaredge

Power Optimizer
For North America
P320 / P340 / P370 / P400 / P405 / P505

Optimizer model (typical module compatibility)	P320 (for 60-cell modules)	P340 (for high-power 60-cell modules)	P370 (for higher-power 60 and 72-cell modules)	P400 (for 72 & 96-cell modules)	P405 (for thin film modules)	P505 (for higher-current modules)	
INPUT							
Rated Input DC Power[1]	320	340	370	400	405	505	W
Absolute Maximum Input Voltage (Voc at lowest temperature)	48		60	80	125[2]	83[2]	Vdc
MPPT Operating Range	8 - 48		8 - 60	8 - 80	12.5 - 105	12.5 - 83	Vdc
Maximum Short Circuit Current (Isc)	9.75			10.1		14	Adc
Maximum DC Input Current	13.75			12.63		17.5	Adc
Maximum Efficiency	99.5						%
Weighted Efficiency	98.8					98.6	%
Overvoltage Category	II						
OUTPUT DURING OPERATION (POWER OPTIMIZER CONNECTED TO OPERATING SOLAREDGE INVERTER)							
Maximum Output Current	15						Adc
Maximum Output Voltage	60					85	Vdc
OUTPUT DURING STANDBY (POWER OPTIMIZER DISCONNECTED FROM SOLAREDGE INVERTER OR SOLAREDGE INVERTER OFF)							
Safety Output Voltage per Power Optimizer	1 ± 0.1						Vdc
STANDARD COMPLIANCE							
EMC	FCC Part15 Class B, IEC61000-6-2, IEC61000-6-3						
Safety	IEC62109-1 (class II safety), UL1741						
RoHS	Yes						
INSTALLATION SPECIFICATIONS							
Maximum Allowed System Voltage	1000						Vdc
Compatible Inverters	All SolarEdge Single Phase and Three Phase inverters						
Dimensions (W x L x H)	128 x 152 x 27.5 / 5 x 6 x 1.1			128 x 152 x 35 / 5 x 6 x 1.4		128 x 152 x 50 / 5 x 6 x 2	mm / in
Weight (including cables)	630 / 1.4			750 / 1.7		845 / 1.9	gr / lb
Input Connector	MC4						
Output Wire Type / Connector	Double Insulated; MC4						
Output Wire Length	0.95 / 3.0			1.2 / 3.9			m / ft
Input Wire Length	0.16 / 0.52						m / ft
Operating Temperature Range	-40 - +85 / -40 - +185						°C / °F
Protection Rating	IP68 / NEMA6P						
Relative Humidity	0 - 100						%

[1] Rated STC power of the module. Module of up to +5% power tolerance allowed

[2] NEC 2017 requires max input voltage be not more than 80V

[3] For other connector types please contact SolarEdge

PV System Design Using a SolarEdge Inverter[3,4]	Single Phase HD-Wave	Single phase	Three Phase 208V	Three Phase 480V	
Minimum String Length (Power Optimizers)	8	10	18		
Maximum String Length (Power Optimizers)	25		50		
Maximum Power per String	5700 (6000 with SE7600-US - SE14KUS)	5250	6000[5]	12750[6]	W
Parallel Strings of Different Lengths or Orientations	Yes				

[4] It is not allowed to mix P405/P505 with P320/P340/P370/P400 in one string.

[5] For 208V grid: It is allowed to install up to 7,200W per string when 13 strings are connected to the inverter (3 strings per MPPT). For other configurations refer to the string calculator.

[6] For 480V grid: It is allowed to install up to 15,000W per string when 25 strings are connected to the inverter (5 strings per MPPT). For other configurations refer to the string calculator.

187

Solar PV Module Specs (trinasolar.com)

Example Sys. #4

THE ALLMAX
FRAMED 60-CELL MODULE

60 CELL
MULTICRYSTALLINE MODULE

260-280W
POWER OUTPUT RANGE

17.1%
MAXIMUM EFFICIENCY

0~+5W
POSITIVE POWER TOLERANCE

Our most versatile product
Compatible with all major BOS components and system designs
Maximize Limited Space
Highly reliable due to stringent quality control
Certified to withstand the most challenging environmental conditions

Trinasolar

FRAMED 60-CELL MODULE

ELECTRICAL DATA (STC)

Peak Power Watts P_{MAX} (Wp)*	260	265	270	275	280
Power Output Tolerance P_{MAX} (W)	0 ~ +5				
Maximum Power Voltage V_{MP} (V)	30.6	30.8	30.9	31.1	31.4
Maximum Power Current I_{MP} (A)	8.50	8.61	8.73	8.84	8.92
Open Circuit Voltage V_{OC} (V)	38.2	38.3	38.4	38.5	38.7
Short Circuit Current I_{SC} (A)	9.00	9.10	9.18	9.25	9.34
Module Efficiency η (%)	15.9	16.2	16.5	16.8	17.1

STC: Irradiance 1000W/m², Cell Temperature 25°C, Air Mass AM1.5.
*Measuring tolerance: ±3%.

ELECTRICAL DATA (NOCT)

Maximum Power P_{MAX} (Wp)	193	197	200	204	207
Maximum Power Voltage V_{MP} (V)	28.4	28.6	28.7	29.0	29.2
Maximum Power Current I_{MP} (A)	6.81	6.89	6.97	7.03	7.10
Open Circuit Voltage V_{OC} (V)	35.4	35.5	35.5	35.6	35.8
Short Circuit Current I_{SC} (A)	7.27	7.35	7.41	7.47	7.55

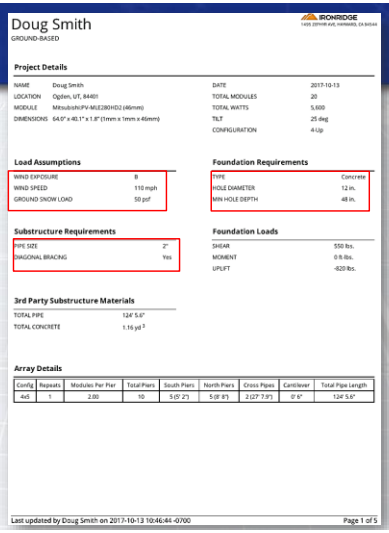
NOCT: Irradiance at 800W/m², Ambient Temperature 20°C, Wind Speed 1m/s.

Comprehensive Products And System Certificates
IEC61215/IEC61730/UL1703/IEC61701/IEC62716
ISO 9001: Quality Management System

188

Example Sys. #4

IronRidge® Ground-Mount Racking Specifications (ironridge.com)


Doug Smith
GROUND-BASED

Project Details

NAME	Doug Smith	DATE	2017-10-13
LOCATION	Ogden, UT, 84401	TOTAL MODULES	20
MODULE	Mitsubishi PV-MLE280HD2 (46mm)	TOTAL WATTS	5,600
DIMENSIONS	64.0" x 40.1" x 1.8" (1mm x 1mm x 46mm)	TILT	25 deg
		CONFIGURATION	4 Up

Load Assumptions

WIND EXPOSURE	B
WIND SPEED	110 mph
GROUND SNOW LOAD	50 psf

Foundation Requirements

TYPE	Concrete
HOLE DIAMETER	12 in.
MIN HOLE DEPTH	48 in.

Substructure Requirements

PIPE SIZE	2"
DIAGONAL BRACING	Yes

Foundation Loads

SHEAR	550 lbs.
MOMENT	0 ft-lbs.
UPLIFT	-820 lbs.

3rd Party Substructure Materials

TOTAL PIPE	124' 5.6"
TOTAL CONCRETE	1.16 yd³

Array Details

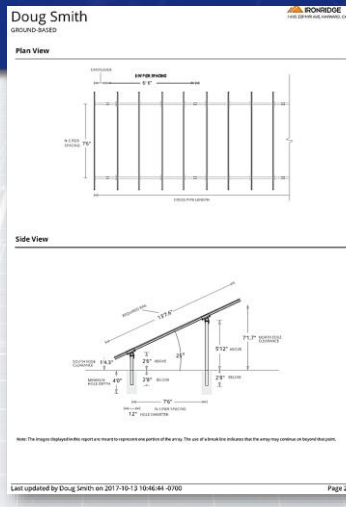
Config	Repeats	Modules Per Pier	Total Piers	South Piers	North Piers	Cross Pipes	Cantilever	Total Pipe Length
4x5	1	2.00	10	5 (5' 2")	5 (8' 8")	2 (27' 7.9")	0' 6"	124' 5.6"

Last updated by Doug Smith on 2017-10-13 10:46:44 -0700 Page 1 of 5

189

Example Sys. #4

IronRidge® Ground-Mount Racking Specifications (ironridge.com)


Doug Smith
GROUND-BASED

Plan View

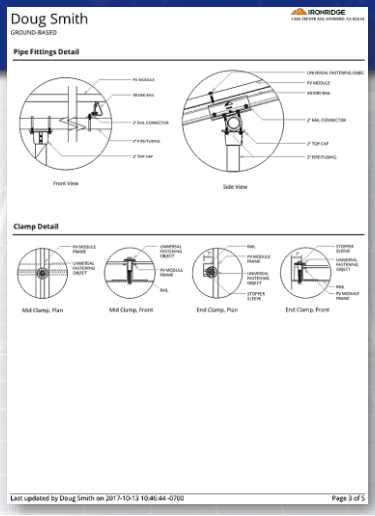
Side View

Last updated by Doug Smith on 2017-10-13 10:46:44 -0700 Page 2 of 5

190

Example Sys. #4

IronRidge® Ground-Mount Racking Specifications (ironridge.com)


Doug Smith
GROUND-BASED

Pipe Fittings Detail

Front View

Side View

Clamp Detail

Mid Clamp, Plan

Mid Clamp, Front

End Clamp, Plan

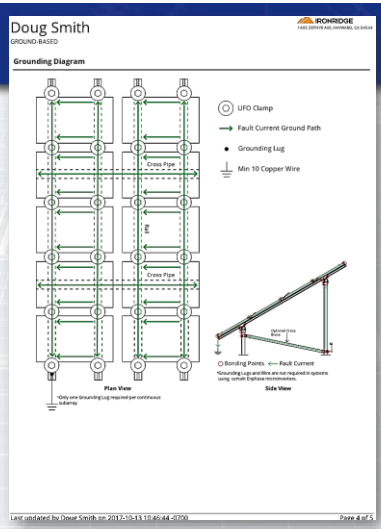
End Clamp, Front

Last updated by Doug Smith on 2017-10-13 10:46:44 -0700 Page 3 of 5

191

Example Sys. #4

IronRidge® Ground-Mount Racking Specifications (ironridge.com)


Doug Smith
GROUND-BASED

Grounding Diagram

UFO Clamp

Fault Current Ground Path

Grounding Lug

Min 10 Copper Wire

Cross Pipe

Cross Pipe

Plan View

Bonding Points ← Fault Current

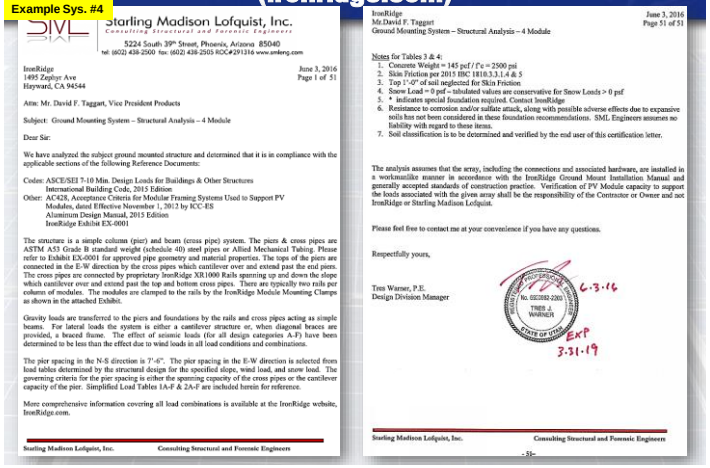
Side View

Last updated by Doug Smith on 2017-10-13 10:46:44 -0700 Page 4 of 5

192

IronRidge® Ground-Mount Racking Specifications (ironridge.com)

Example Sys. #4



Starling Madison Lofquist, Inc.
Consulting Structural and Forensic Engineers
5224 South 39th Street, Phoenix, Arizona 85040
tel: (602) 438-2500 fax: (602) 438-2505 ROC#291316 www.smleng.com

IronRidge
1495 Zephyr Ave
Hayward, CA 94544

June 3, 2016
Page 1 of 51

Attn: Mr. David F. Taggart, Vice President Products

Subject: Ground Mounting System – Structural Analysis – 4 Module

Dear Sir:

We have analyzed the subject ground mounted structure and determined that it is in compliance with the applicable sections of the following Reference Documents:

Codes: ASCE/SEI 7-10 Min. Design Loads for Buildings & Other Structures
International Building Code, 2015 Edition
Other: AC428, Acceptance Criteria for Modular Framing Systems Used to Support PV Modules, dated Effective November 1, 2012 by ICC-ES
Aluminum Design Manual, 2015 Edition
IronRidge Exhibit EX-0001

The structure is a simple column (pier) and beam (cross pipe) system. The piers & cross pipes are ASTM A53 Grade B standard weight (schedule 40) steel pipes or Allied Mechanical Tubing. Please refer to Exhibit EX-0001 for approved pipe geometry and material properties. The tops of the piers are connected in the E-W direction by the cross pipes which cantilever over and extend past the end piers. The cross pipes are connected by proprietary IronRidge XR1000 Rails spanning up and down the slope which cantilever over and extend past the top and bottom cross pipes. There are typically two rails per column of modules. The modules are clamped to the rails by the IronRidge Module Mounting Clamps as shown in the attached Exhibit.

Gravity loads are transferred to the piers and foundations by the rails and cross pipes acting as simple beams. For lateral loads the system is either a cantilever structure or, when diagonal braces are provided, a braced frame. The effect of seismic loads (for all design categories A-F) have been determined to be less than the effect due to wind loads in all load conditions and combinations.

The pier spacing in the N-S direction is 7'-6". The pier spacing in the E-W direction is selected from load tables determined by the structural design for the specified slope, wind load, and snow load. The governing criteria for the pier spacing is either the spanning capacity of the cross pipes or the cantilever capacity of the pier. Simplified Load Tables 1A-F & 2A-F are included herein for reference.

More comprehensive information covering all load combinations is available at the IronRidge website, IronRidge.com.

Starling Madison Lofquist, Inc. Consulting Structural and Forensic Engineers

IronRidge
Mr.David F. Taggart
Ground Mounting System – Structural Analysis – 4 Module

June 3, 2016
Page 51 of 51

Notes for Tables 3 & 4:
1. Concrete Weight = 145 pcf / f'c = 2500 psi
2. Skin Friction per 2015 IBC 1810.3.3.1.4 & 5
3. Top 1'-0" of soil neglected for Skin Friction
4. Snow Load = 0 psf – tabulated values are conservative for Snow Loads > 0 psf
5. * Indicates special foundation required. Contact IronRidge
6. Resistance to corrosion and/or sulfate attack, along with possible adverse effects due to expansive soils has not been considered in these foundation recommendations. SML Engineers assumes no liability with regard to these items.
7. Soil classification is to be determined and verified by the end user of this certification letter.

The analysis assumes that the array, including the connections and associated hardware, are installed in a workmanlike manner in accordance with the IronRidge Ground Mount Installation Manual and generally accepted standards of construction practice. Verification of PV Module capacity to support the loads associated with the given array shall be the responsibility of the Contractor or Owner and not IronRidge or Starling Madison Lofquist.

Please feel free to contact me at your convenience if you have any questions.

Respectfully yours,

Tres Warner, P.E.
Design Division Manager

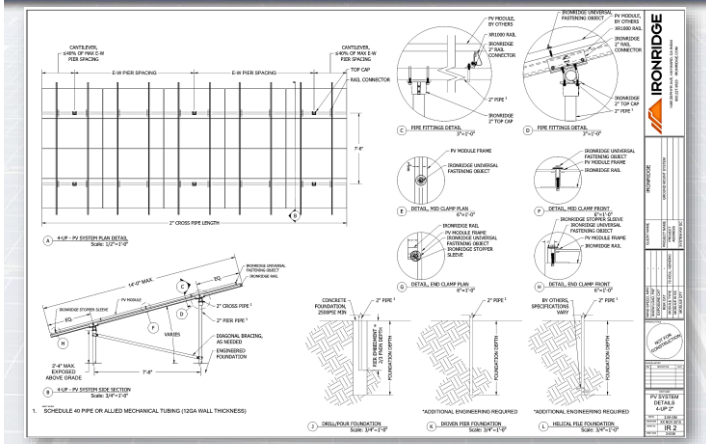
TRES A. WARNER No. 6023882-2202 STATE OF UTAH
6.3.16
EXP 3.31.19

Starling Madison Lofquist, Inc. Consulting Structural and Forensic Engineers

193

IronRidge® Ground-Mount Racking Specifications (ironridge.com)

Example Sys. #4



194

IronRidge® Ground-Mount Racking Specifications (ironridge.com)

Example Sys. #4

195

Signage

Example Sys. #4

All signage must be permanently attached and be able to withstand the environment they are installed. Signage also cannot be hand-written. *NEC* 110.21(B).

CAUTION: MULTIPLE SOURCES OF POWER

The above shown sign is required at the service disconnect. *NEC* 705.10.

Note: 2nd PV inverter is located at ground-mounted solar array behind home.

A sign is required at the home's service meter panelboard noting the location of the 2nd **string** inverter since it's not located next to the utility service panel. *NEC* 690.4(D). Wording could vary.

Maximum DC Voltage = [redacted]

This sign is required to be mounted on the **string** inverter. *NEC* 690.53

WARNING: POWER SOURCE OUTPUT DO NOT RELOCATE THIS OVERCURRENT DEVICE.

This sign is required to be located next to the AC PV backfed breaker(s) **ONLY if** the 120% allowance of *NEC* 705.12(B)(3)(2) is being utilized.

PV System: AC Current = 50A AC Volts = 240V

This sign is required to be located at the backfed panelboard. *NEC* 690.54 (in the **2020 *NEC***).

SOLAR PV SYSTEM EQUIPPED WITH RAPID SHUTDOWN

TURN RAPID SHUTDOWN SWITCH TO THE "OFF" POSITION TO SHUTDOWN PV SYSTEM AND REDUCE SHOCK HAZARD IN ARRAY

This sign to be located on the outside of, and within 3' of the service equipment. *NEC* 690.56(C).

RAPID SHUTDOWN SWITCH FOR SOLAR PV SYSTEM

This sign must be reflective and is required to be located next to the disconnect switch which activates rapid shutdown. *NEC* 690.56(C)(2) **(for this system, it would be at the 70A tie-in breaker in the service or the PV AC disconnect switch near service – if provided)**

PHOTOVOLTAIC POWER SOURCE

This sign is to be located on the outside of any conduits, enclosures, or MC cable that contain **DC** circuits. The markings shall **be reflective** and be provided at every enclosure, every 10' along conduit or MC cable, and at each side of where the conduit or cable passes through a wall, floor, or any other partition. The markings shall be permanently affixed and visible after installation. *NEC* 690.31(D)(2)

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196

ESS Example System #5

SolarEdge® StorEdge HUB™ Battery Backup String Inverter with an LG Chem® DC Battery System

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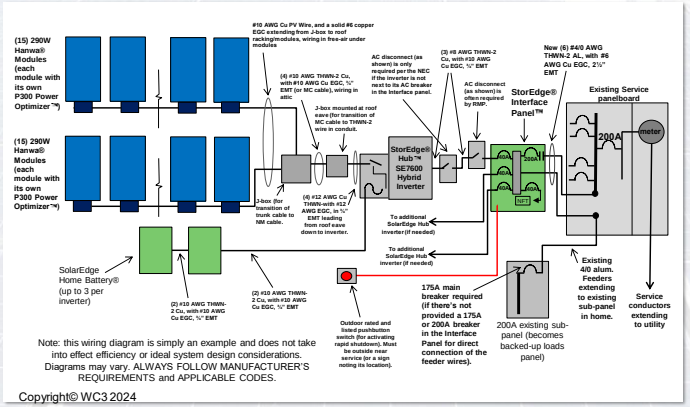
197

Example System (for an SolarEdge® Hub™ battery system

ESS Example Sys. #5



Note: this wiring diagram is simply an example and does not take into effect efficiency or ideal system design considerations. Diagrams may vary. ALWAYS FOLLOW MANUFACTURER'S REQUIREMENTS and APPLICABLE CODES.

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198

Site Plan (gabled roof)

ESS Example Sys. #5

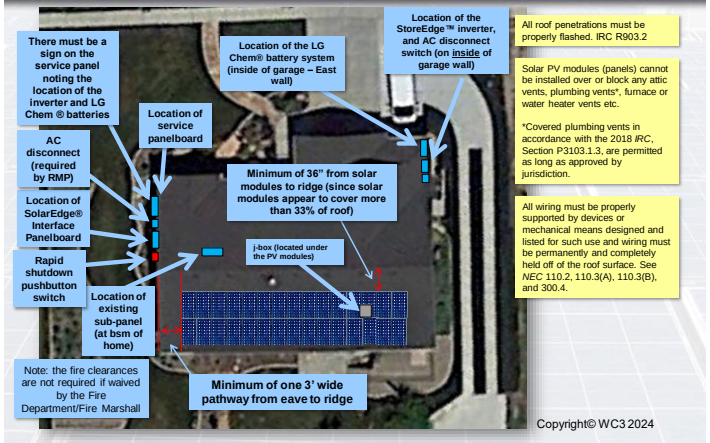

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Photo of Service Panel

ESS Example Sys. #5

For this example, we are assuming that the service panel is rated for **200A** since the main service breaker is rated **200A**.

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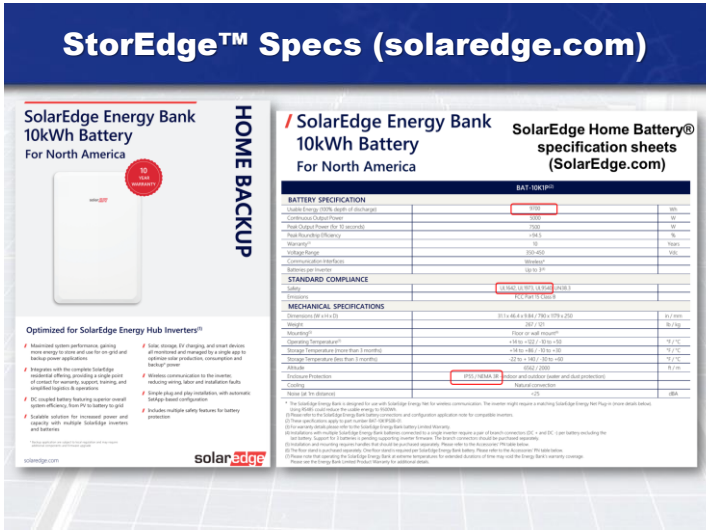
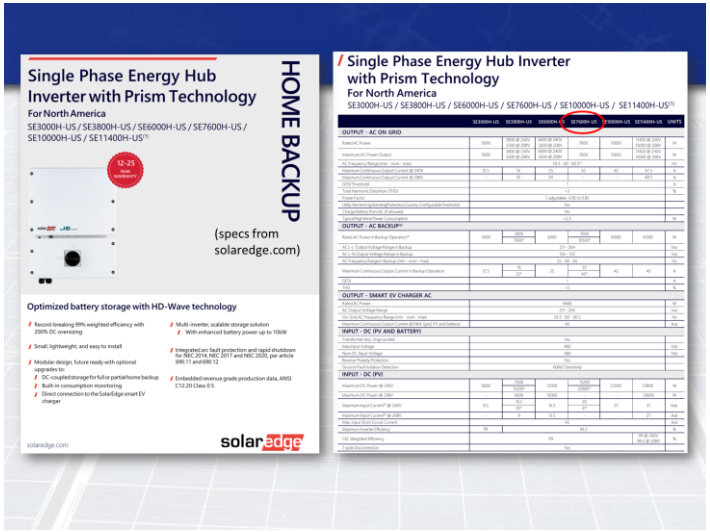
StorEdge™ Specs (solaredge.com)



201



202

Single Phase Energy Hub Inverter with Prism Technology

For North America

SE3000H-US / SE3800H-US / SE6000H-US / SE7600H-US / SE10000H-US / SE11400H-US(1)

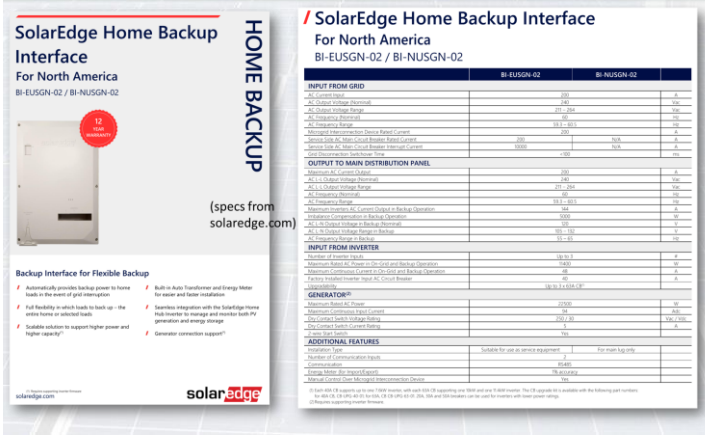
	SE3000H-US	SE3800H-US	SE6000H-US	SE7600H-US	SE10000H-US	SE11400H-US	UNITS
INPUT - DC (BATTERY)							
Supported Battery Types	SolarEdge Energy Bank, LG RESU Prime(2)						
Number of Batteries per Inverter	Up to 3 SolarEdge Energy Bank, up to 2 LG RESU Prime						
Continuous Power(3)	6000	7600		10000			W
Peak Power(4)	6000	7600		10000			W
Max Input Current	16	20		26.5			Adc
2-pole Disconnection	Yes						
SMART ENERGY CAPABILITIES							
Consumption Metering	Built-in(5)						
Backup & Battery Storage	With Backup Interface (purchased separately) for service up to 200A; Up to 3 inverters						
EV Charging	Direct connection to Smart EV charger						
ADDITIONAL FEATURES							
Supported Communication Interfaces	RS485, Ethernet, Cellular(6), Wi-Fi (optional), SolarEdge Energy Net (optional)						
Revenue Grade Metering, ANSI C12.20	Built-in(5)						
Integrated AC, DC and Communication Connection Unit	Yes						
Inverter Commissioning	With the SetApp mobile application using built-in Wi-Fi Access Point for local connection						
DC Voltage Rapid Shutdown (PV and Battery)	Yes, according to NEC 2014, NEC 2017 and NEC 2020 690.12						
STANDARD COMPLIANCE							
Safety	UL1741, UL1741 SA, UL1741 PCS, UL 9998, UL 9998, UL 9540, CSA 22.2						
Grid Connection Standards	IEEE1547, Rule 21, Rule 14H						
Emissions	FCC part 15 class B						
INSTALLATION SPECIFICATIONS							
AC Output and EV AC Output Conduit Size / AWG Range	1" maximum / 14-4 AWG						
DC Input (PV and Battery) Conduit Size / AWG Range	1" maximum / 14-6 AWG						
Dimensions with Connection Unit (H x W x D)	17.7 x 14.6 x 6.8 / 450 x 370 x 174			17.7 x 14.6 x 8.8 / 450 x 370 x 174	17.7 x 14.6 x 6.8 / 450 x 370 x 174		in / mm
Weight with Connection Unit	26 / 11.8			26 / 11.8	41.7 / 18.9		lb / kg
Noise	< 25	< 25 / < 50*		< 25	< 50		dBA
Cooling	Natural Convection						
Operating Temperature Range	-40 to +140 / -40 to +60(8)						°F / °C
Protection Rating	NEMA 4						

(specs from solaredge.com)

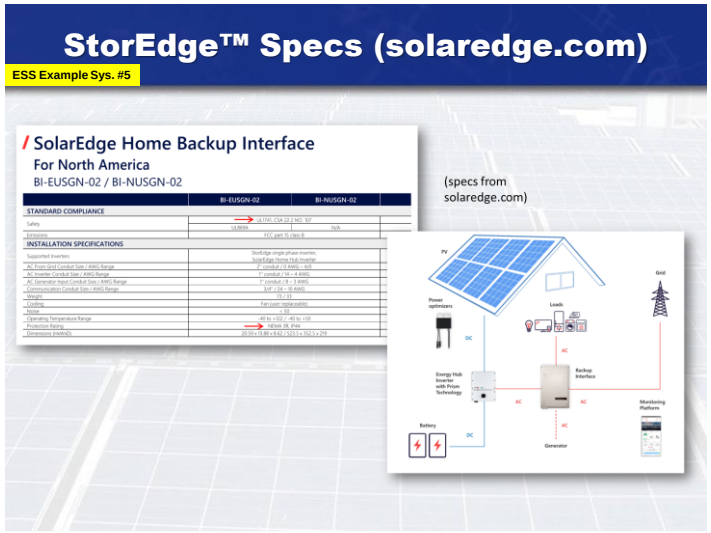
203

StorEdge™ Specs (solaredge.com)

ESS Example Sys. #5



204



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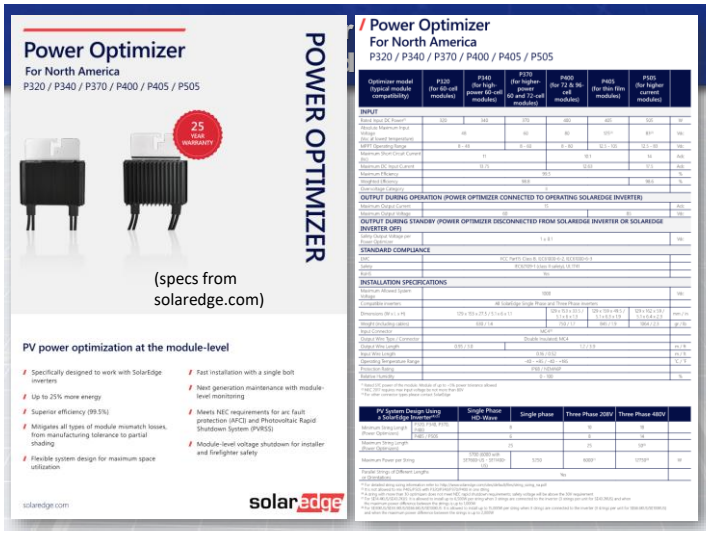
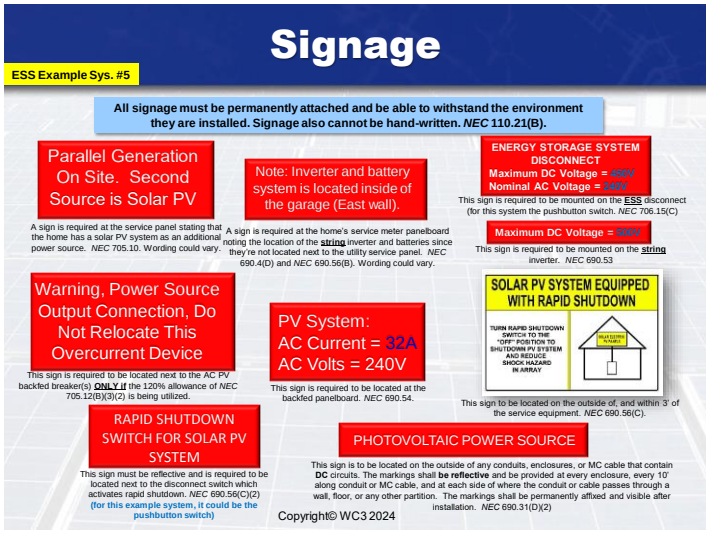


206

207



208

ESS Example System #6

Enphase® Encharge 10™ Energy Storage System with Enphase® Micro Inverters

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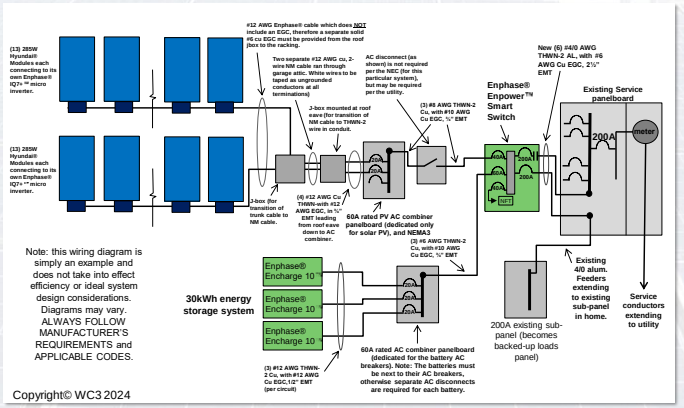
209

Example System (for an Enphase® Encharge 10™ and IQ7+™ micro inverter system)

ESS Example Sys. #6



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210

Site Plan

ESS Example Sys. #6

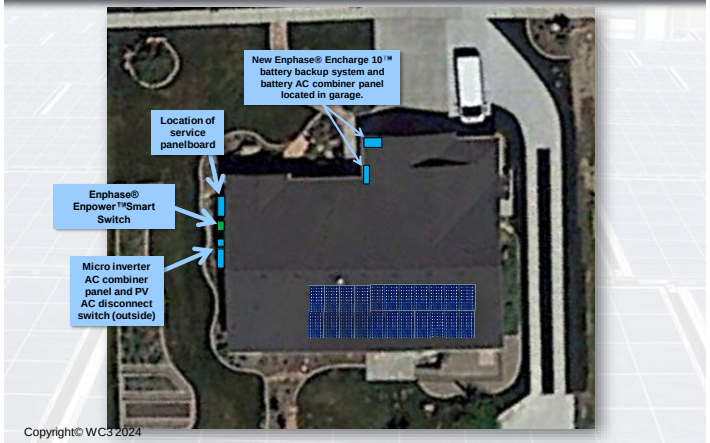

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Photo of Service Panel

ESS Example Sys. #6

Typically, photos of the service panel label are needed in order to show the rating of the service (and rating of breaker slots).

Also, a clear photo showing the rating of the main service breaker(s) is usually required (in order to determine load-side connection rules).

For this example, we are assuming that the service panel is rated for **200A** since the main service breaker is rated **200A**.

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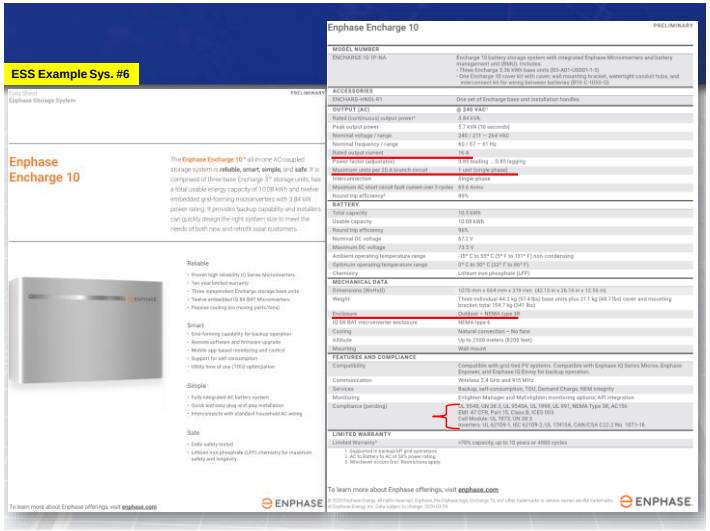
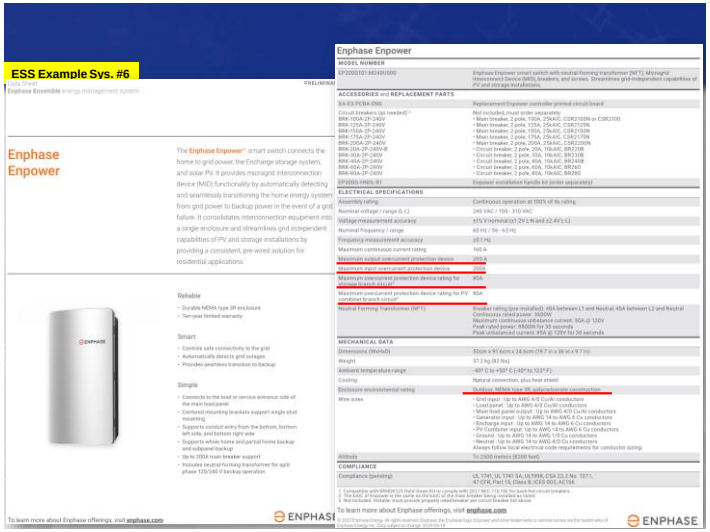
212



213

214



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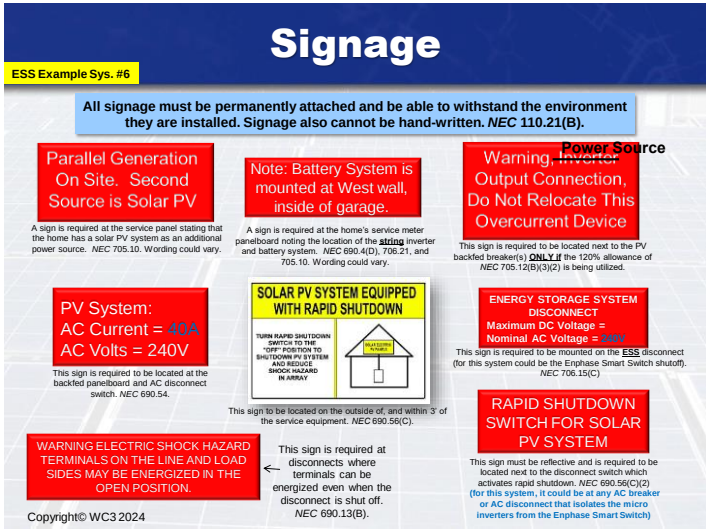

216

217