Simplified Solar Permitting Guidelines

Improving Permit Review and Inspection for Small Solar Systems

SolSmart Training

Bill Brooks, Principal, Brooks Engineering
The information in these guidelines are intended to provide a format whereby local jurisdictions and contractors can permit simple PV system installations where only a basic review is necessary.

It is likely that most residential and some small commercial PV systems will comply with these simple criteria that address the requirements for PV systems in the building, electrical, and fire codes.
Guideline Contents

1. **Eligibility List** – Defines the size, electrical, structural, and fire safety requirements for solar installations to qualify for simplified permitting.

2. **Structural Review** – Enable applicants to “fill in the blanks” to explain the structural details of a rooftop solar PV system.

3. **Electrical Review** – Enable applicants to “fill in the blanks” to explain the electrical configuration of a solar PV system.
This Guideline is not intended to create, explicitly or implicitly, any new requirements.

- NEC Article 690, 705, and chapters 1-4
- IRC R331, R902, R905, R908
- IBC 1505, 1509, 1511
- IFC 605.11
- ASCE 7-10, 7-16
Required Information for Permit:

1. Permit application required by the local jurisdiction. Permit applications normally include information about the project scope, project location, and the installer.

2. Site plan showing location of major components on the property. This drawing need not be exactly to scale, but it should represent relative location of components at site (see supplied example site plan). PV arrays in compliance with IRC fire setback requirements need no separate fire service review (with Fire Service MOU).
Required Information for Permit (cont.):  

3. Electrical worksheets showing PV array configuration, wiring system, overcurrent protection, inverter, disconnects, required signs, and ac connection to building (see supplied standard electrical diagram).

4. Specification sheets and installation manuals (if available) for all major PV system components such as, PV modules, dc-to-dc converters, inverters, and mounting systems.
Purposes of Simplified Permitting

• A simplified, expedited permit process for small solar PV systems simplifies and consolidates the structural, electrical and fire review of the PV system.

• It can eliminate the need for detailed engineering studies and often avoids unnecessary delays.

• It is not the intent of an expedited process to circumvent the engineering process.

• It is to recognize the similarities among these smaller systems and establish guidelines to determine when a PV project is within the boundaries of typical, well-engineered systems that are clearly compliant with electrical and building codes.
Elements of Streamlined Inspection

• Use of a concise inspection list
• Enable inspection requests (phone, online, or email).
• Provide for on-site inspection during the next business day (where possible and no more than 5 days).
• Provide a scheduling time window for on-site inspection of no more than two hours. (phone and/or email confirmation)
• May include notification of the utility of successful completion.
The “Box” to Qualify Simple Permits

- PV system no larger than 15.36kW
- One- and two-family rooftop installations or structure of same construction.
- String inverter, dc converter, or microinverter
- Complies with eligibility checklist
High Level Analysis of Guideline

Small Residential PV Systems—Simple

- 15.36 kWac or less—no larger than 80A PV system circuit breaker connection
- String inverter, microinverter, or dc converter

PV system options
Submittal Requirements Bulletin Solar Photovoltaic Installations In One- and Two-Family Dwellings (and like structures)

- Guides applicants through permitting process. Provides information about submittal requirements for plan review.
ELIGIBILITY CHECKLIST FOR SIMPLIFIED PV PERMITTING

A PV project that conforms to all the items on this list is eligible for simplified permitting

Step 1: Structural PV Array Mounting Requirements Checklist—Items for both member- and sheathing-attached systems.

A. General Site and Array Requirements (all square boxes must be checked; where slanted check box sub-options occur, one sub-option must be checked):

☐ 1. Wind Exposure and Design Wind Speed (as defined by ASCE 7-10, select one below):
   - □ a. Member-Attached System: Exposure B or C and design wind speed does not exceed 150 mph.
ELIGIBILITY CHECKLIST FOR SIMPLIFIED PV PERMITTING

A PV project that conforms to all the items on this list is eligible for simplified permitting

Step 1: Structural PV Array Mounting Requirements Checklist—Items for both member- and sheathing-attached systems.

☐ 2. The structure is not in Wind Exposure D (within 200 yards of a body water wider than a mile).
☐ 3. The structure is not on a hill with a grade steeper than 5%, where topographic effects can significantly increase wind loads.
☐ 4. Ground snow loads do not exceed 60 psf
☐ 5. Distributed weight of PV array is less than 4 lbs/ft\(^2\) (less than 5 lbs/ft\(^2\) for thermal systems).
ELIGIBILITY CHECKLIST FOR SIMPLIFIED PV PERMITTING

B. Roof Information (all must apply):

☐ 1. The array is mounted on a permitted one- or two-family roof structure or similar structure. *If roof not permitted, show compliance with International Residential Code (IRC) span tables.*

☐ 2. The roof is framed with wood rafters or trusses at no greater than 48” on center. Roof framing members run upslope/downslope. (not horizontal purlins)

☐ 3. The roof structure appears to be structurally sound, without signs of alterations or significant structural deterioration or sagging.

☐ 4. Sheathing: At least 7/16” or thicker plywood, or 7/16” or thicker oriented strand board (OSB).

☐ 5. If a composition shingle roof, the roof has a single roof overlay (no multiple shingle layers). *If not, show compliance with IRC span tables.*

☐ 6. Mean roof height is not greater than ☐ 40 ft (member-attached), ☐ 30 ft (sheathing-attached).

☐ 7. In areas of significant seismic activity (Seismic Category C, D, E or F), PV array covers no greater than half the total area of the roof (all roofs included).
C. Array Mounting Equipment Information (*all must be defined*):

- 1. Mounting Equipment Manufacturer ________________________________
- 2. Product Name and Model#________________________________________
- 3. UL2703 fire rating for the PV modules used in the project. Fire rating Class_______ (A, B, or C).
- 4. Specify anchor-to-roof sealing (e.g. flashing, or sealant compatible with roofing):________________________________________________________
Member-Attached PV Array Requirements:

☐ 1. Array is set back from all roof edges and ridge by at least twice the gap under the modules (or more, where fire access pathways are required).

☐ 2. Array does not cantilever over the perimeter anchors more than 19”.

☐ 3. Gap under modules (roof surface to underside of module) is no greater than 10”.

☐ 4. Gaps between modules are (select one below):
   ☐ a. at least 0.25” on both short and long sides of modules, or
   ☐ b. 0” on short side, and at least 0.50” on long sides.
Member-Attached PV Array Requirements (cont):

- **5.** Mounting rail orientation or rail-less module long edges (select one below):
  - a. run perpendicular to rafters or trusses, and attached to them, or
  - b. run parallel to rafters and are spaced no more than 4’-0” apart, Ground Snow Load is no greater than 10 psf, and Design Wind Speed does not exceed 120 mph.

- **6.** The anchor/mount/stand-off spacing perpendicular to rafters or trusses (select one below):
  - a. does not exceed 4’-0”, and anchors in adjacent rows are staggered where rafters or trusses are at 24” or less on center (see Figure), or
  - b. does not exceed 4’-0”, anchor layout is orthogonal, roof slope is 6:12 or less, Ground Snow Load is no greater than 10 psf, and Design Wind Speed does not exceed 120 mph, or
  - c. does not exceed 6’-0”, anchor layout is orthogonal, roof slope is 6:12 or less, Ground Snow Load is zero, and Design Wind Speed does not exceed 120 mph.
Member-Attached PV Array Requirements (cont):

☐ 7. Upslope/downslope anchor spacing follows manufacturer’s instructions.

☐ 8. Anchor fastener is (select one below):
   ☐ a. 5/16” diameter lag screw with 2.5” embedment into structural member, or
   ☐ b. fastener other than (a.) embedded in structural members in accordance with manufacturer’s structural attachment details. Manufacturer’s anchor layout requirements must not exceed the anchor spacing requirements shown in Items 5 and 6 above.
Sheathing-Attached PV Array Requirements:

1. Array is set back from all roof edges and ridge by at least twice the gap under the modules (or more, where fire access pathways are required).
2. Array does not cantilever over the perimeter anchors more than 19”.
3. Gap under modules (roof surface to underside of module) is no greater than 5”.
4. Gap between modules is at least 0.75” on both short and long sides of modules.
5. Roof slope is 2:12 (9 degrees) or greater.
ELIGIBILITY CHECKLIST FOR SIMPLIFIED PV PERMITTING

Sheathing-Attached PV Array Requirements (cont):

☐ 5. Roof framing and sheathing nailing options (select a, b, or c below):
   ☐ a. Manufactured Wood Trusses, or
   ☐ b. Initially Dry Wood Rafters (lumber grade stamps are visible and state “S-DRY” (Surfaced Dry) or “KD” (Kiln-Dried), or
   ☐ c. Initially Wet Wood Rafters meeting one of the field-verified sheathing nail options listed below. Note: If lumber stamps are not visible, or if lumber stamps state “S-GRN” (Surfaced Green), the lumber shall be assumed to have been initially “wet” (MC > 19%) at time of sheathing installation. (select i, ii, or iii below):
      ☐ i. Deformed shank nails, 6d or greater, or
      ☐ iii. 6d or 8d smooth shank common or box nails, nailed into dense lumber, either Douglas Fir (stamp: DF or DF-L) or Southern Pine (stamp: SPIB).

(Note: sheathing attached not allowed with Lower density lumber such as Spruce-Pine-Fir (stamp: S-P-F) and Hem-Fir (stamp: HF) with smooth shank nails.)
Sheathing-Attached PV Array Requirements (cont):

- 6. Anchor location restrictions—all anchors must comply with at least one of the options below. Anchors verified to be in “Bands of Strength” are attached in the middle 16” wide strip centered between the long edges of sheathing panels (at least 16” from sheathing long edge). Check all boxes that apply to anchors in the array:
a. Some anchors are not within bands of strength, and all the following (i., ii. & iii.) apply:

- i. Edge of array is more than 3 feet from any roof edge (Wind Zone 1), and
- ii. Tributary area is 9 ft\(^2\) or less (up to half the area of a 60 cell PV module), and
- iii. Wind Exposure B only, and design wind speed does not exceed 120 mph.
b. All anchors are within bands of strength, and all of the following (i., ii. & iii.) apply:

- i. Edge of array is more than 3 feet from any roof edge (Wind Zone 1), and
- ii. Tributary area is 14 ft² or less (40”x48”).
- iii. One of the two wind cases below (x. or y.) applies:
  - x. Exposure B, and design wind speed does not exceed 140 mph, or
  - y. Exposure C, and design wind speed does not exceed 120 mph.
c. All anchors are within bands of strength, and all the following (i., ii. & iii.) apply:
   - i. Edge of array meets E.1 and is within 3 feet of a roof edge (Wind Zone 2), and
   - ii. Tributary area including cantilevers is 9 ft² or less (32.5”X40”).
   - iii. Wind Exposure B only, and design wind speed does not exceed 120 mph.

d. All anchors are within bands of strength, and all the following (i., ii. & iii.) apply:
   - i. Edge of array meets E.1 and is within 3 feet of a roof corner (Wind Zone 3), and
   - ii. Tributary area, including cantilevers, is 4.5 ft² or less (32.5”X20”).
   - iii. Wind Exposure B only, and design wind speed does not exceed 120 mph.
ELIGIBILITY CHECKLIST FOR SIMPLIFIED PV PERMITTING

☐ 8. Anchor-to-sheathing connection has an allowable stress design (ASD) uplift capacity of at least 166 lbs. under short duration loading, which corresponds to a mean ultimate tested uplift capacity of at least 520 lbs.

GENERAL STATEMENT FOR CHECKLIST:

If any structural item cannot be checked off, the building official may require the installer to provide structural calculations and/or details, stamped and signed by a design professional, addressing the unchecked item.
<table>
<thead>
<tr>
<th>Mount Substrate</th>
<th>Rule Section</th>
<th>Mount Spacing</th>
<th>Mount Layout</th>
<th>Snow Load</th>
<th>Roof Slope</th>
<th>Location in Allowed Zones</th>
<th>Max. Design Wind Speed</th>
<th>Allowed Exposures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rafter-Attached</td>
<td>D.6.a</td>
<td>48&quot; cross-slope¹</td>
<td>staggered</td>
<td>60 psf</td>
<td>any</td>
<td>rafter centerline +/- 1/4&quot;</td>
<td>150 mph</td>
<td>B &amp; C</td>
</tr>
<tr>
<td>&quot;</td>
<td>D.6.b</td>
<td>48&quot; cross-slope¹</td>
<td>orthogonal</td>
<td>10 psf</td>
<td>flat to 6:12</td>
<td>&quot;</td>
<td>120 mph</td>
<td>&quot;</td>
</tr>
<tr>
<td>&quot;</td>
<td>D.6.c</td>
<td>72&quot; cross-slope¹</td>
<td>&quot;</td>
<td>0 psf</td>
<td>&quot;</td>
<td>&quot;</td>
<td>120 mph</td>
<td>&quot;</td>
</tr>
<tr>
<td>Sheathing-Attached</td>
<td>E.7.a</td>
<td>40&quot;x33&quot;</td>
<td>orthogonal</td>
<td>60 psf</td>
<td>2:12 to vert.</td>
<td>anywhere in Zone 1</td>
<td>120 mph</td>
<td>B</td>
</tr>
<tr>
<td>&quot;</td>
<td>E.7.b.iii.x</td>
<td>40&quot;x48&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
<td>bands of strength²</td>
<td>140 mph</td>
<td>B</td>
</tr>
<tr>
<td>&quot;</td>
<td>E.7.b.iii.y</td>
<td>40&quot;x48&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
<td>120 mph</td>
<td>B &amp; C</td>
</tr>
<tr>
<td>&quot;</td>
<td>E.7.c</td>
<td>40&quot;x33&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
<td>120 mph</td>
<td>B</td>
</tr>
<tr>
<td>&quot;</td>
<td>E.7.d</td>
<td>20&quot;x33&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
<td></td>
</tr>
</tbody>
</table>

¹ Cross-slope mount spacing may also be described as "left-to-right" spacing, or for south-facing sloped roofs, "east-to-west" spacing.

² "Bands of strength" are 16 inch wide swaths (8" to each side of centerline) located midway between the long edges of sheathing panels. Both "bands of strength" typically run cross-slope, perpendicular to rafters.

³ Moisture content of rafters when sheathing was nailed down. Dry = lumber with stamps noting Surface-Dried (SD, S-Dry) or Kiln-Dried (KD or K-Dry). Either = all other cases.

⁴ Soft= Spruce-Pine-Fir (SPF, G=0.42), Hem-Fir (HF, G=0.43). Med. = Douglas Fir (DF or DF-L, G=0.49) or Southern Pine (SPIB, G=0.55). "Either" = soft or med. density lumber.

⁵ 6d common smooth or deformed shank; 8d box or common, smooth or deformed shank. "Any" indicates any sheathing nails or staples that were code compliant at time of installation. "Either" indicates either Case (1) initially dry + either soft- or medium-density lumber (Rule E.6.a), or Case (2) initially either wet or dry + medium-density lumber.
Step 2: Electrical PV System Requirements Checklist

For a simplified PV permit, following are the electrical requirements:

1. Major electrical components including PV modules, dc-to-dc converters, and inverters, are identified for use in PV systems.
2. Array mounting system UL2703 certified for bonding and grounding. Alternatively, the array mounting system may incorporate UL2703 grounding devices to bond separate exposed metal parts together or to the equipment grounding conductor.
3. The PV array consists of no more than 2 series strings per inverter input and no more than 4 series strings in total per inverter.
ELIGIBILITY CHECKLIST FOR SIMPLIFIED PV PERMITTING

4. Field Installed PV array wiring meets the following requirements:
   a. All exposed PV source circuit wiring is 10 AWG PV Wire.
   b. All PV source circuit wiring in raceway is 10 AWG THWN-2, XHHW-2, or RHW-2.
   c. Any field-installed PV output circuit wiring is 6 AWG THWN-2, XHHW-2, or RHW-2.
   d. PV system circuits on buildings meet requirements for controlled conductors in 690.12.

5. The total inverter capacity has a continuous ac power output 15,360 Watts or less and meets the requirements of 705.12(D) where installed on the load side of the service disconnecting means (complies with Table 705.12(D) in Technical Appendix). (choose one below)
   - Load-side connection complying with Table 705.12(D)
   - Supply-side connection complying with 705.12(A)
ELIGIBILITY CHECKLIST FOR SIMPLIFIED PV PERMITTING

6. Equipment is rated for the maximum dc voltage applied to the equipment (put N/A in all blanks that do not apply to the specific installation):

A. ASHRAE Extreme Annual Mean Minimum Design Dry Bulb Temperature (one source is www.solarabcs.org/permitting) =________;
   Table 690.7 (NEC) value____________

B. Max (temp adjusted) module Voc:
   Rated Voc _______V x Table 690.7 value_______ =_________V
C. Dc-to-dc converter(s) or microinverter rated maximum input voltage:________V  
   (must be greater than Max module Voc in (B.))
D. Maximum number of dc-to-dc converters allowed in series (up to 600Vdc):__________
E. Maximum voltage of dc-to-dc converter circuit with maximum number in (C.):________V
ELIGIBILITY CHECKLIST FOR SIMPLIFIED PV PERMITTING

F. Inverter(s) rated maximum input voltage: ________V (must be greater than 1)-4) below)

1) Inverter 1 input 1: Max module Voc (B.) ________V x # in series ______ = ________V

2) Inverter 1 input 2: Max module Voc (B.) ________V x # in series ______ = ________V

3) Inverter 2 input 1: Max module Voc (B.) ________V x # in series ______ = ________V

4) Inverter 2 input 2: Max module Voc (B.) ________V x # in series ______ = ________V
ELIGIBILITY CHECKLIST FOR SIMPLIFIED PV PERMITTING

7. One of the standard electrical diagrams can be used to accurately represent the PV system.

*Fill out the appropriate standard electrical diagram completely. If the electrical system is more complex than the standard electrical diagram can effectively communicate, the project does not meet the requirements for a simplified permit application and additional information may be necessary for the jurisdiction to process the permit application.*
Central/String Inverter Standard Plans

- Use this plan ONLY for central/string inverter systems with or without dc converters not exceeding 15.36kW on the roof of a one- or two-family dwelling or similar structure.
- The photovoltaic system must interconnect to the load side of a 120/240Vac service panel rated 400A or less (80-amp PV breaker or less).
- Not intended for more than two inverters, or more than one dc combiner per inverter (non-inverter-integrated).
Central/String Inverter Standard Plans

Manufacturer’s specification sheets and installation instructions for:

- Inverter
- PV modules
- Added combiner box(es)
- Racking system (including bonding and grounding instructions).
Central/String Inverter Standard Plans

One-Line Standard Electrical Diagram for Small-Scale, Single-Phase PV Systems

Contractor Name, Address and Phone:

Site Name:

Site Address:

System AC Size:

Drawn By:

Checked By:

Not to Scale

Date:

Sheet
Microinverter Standard Plans--Scope

• Use this plan ONLY for systems using microinverters or ac modules (ACM) not exceeding 15.36 kW, with no more than 4 output circuits, one PV module/microinverter, installed on the roof of a one- or two-family dwelling or similar structure.

• The PV system must interconnect to the load side of a 120/240Vac, service panel rated 400A or less (80-amp breaker or less).
Microinverter Standard Plans

Manufacturer’s specification sheets and/or installation instructions for:

- microinverter
- PV modules
- Racking system (including bonding and grounding instructions).
Microinverter Standard Plans

NOTES FOR ALL DRAWINGS:

OCPD = OVERCURRENT PROTECTION DEVICE

NATIONAL ELECTRICAL CODE® REFERENCES SHOWN AS (NEC XXX.XX)

DC-TO-DC CONVERTER RATINGS (if used)

<table>
<thead>
<tr>
<th>CONVERTER MAKE</th>
<th>CONVERTER MODEL</th>
<th>MAX CURRENT</th>
<th>MAX VOLTAGE</th>
<th>MAXIMUM POWER</th>
<th>MAX OUTPUT CIRCUIT V (TYP 600Vdc)</th>
</tr>
</thead>
</table>

INVERTER RATINGS (Guide Section 4)

<table>
<thead>
<tr>
<th>INVERTER MAKE</th>
<th>INVERTER MODEL</th>
<th>MAX DC VOLT RATING</th>
<th>MAX POWER @ 40°C</th>
<th>NOMINAL AC VOLTAGE</th>
<th>MAX AC CURRENT</th>
<th>MAX OCPD RATING</th>
</tr>
</thead>
</table>

1) IF UTILITY REQUIRES A VISIBLE-BREAK SWITCH, DOES THIS SWITCH MEET THE REQUIREMENT? YES ☐ NO ☐ N/A ☐

2) IF GENERATION METER REQUIRED, DOES THIS METER SOCKET MEET THE REQUIREMENT? YES ☐ NO ☐ N/A ☐

3) SIZE INVERTER OUTPUT CIRCUIT (AC) CONDUCTORS ACCORDING TO INVERTER OCPD AMPERE RATING. (See Table xxx)

4) TOTAL OF INVERTER OCPD(s), ONE FOR EACH INVERTER, DOES TOTAL SUPPLY BREAKERS COMPLY WITH 120% BUSBAR RULE IN 705.12(D)? YES ☐ NO ☐

NOTE FOR ARRAY CIRCUIT WIRING (Guide Section 4 and Appendix E):

LOWEST EXPECTED AMBIENT TEMPERATURE BASED ON ASHRAE MINIMUM MEAN EXTREME DRY BULB TEMPERATURE FOR ASHRAE LOCATION MOST SIMILAR TO INSTALLATION LOCATION. LOWEST EXPECTED AMBIENT TEMP ___________°C

NOTES FOR INVERTER CIRCUITS (Section 4): *NOTE: MICROINVERTER AND AC MODULE SYSTEMS DO NOT NEED DC DISCONNECT 
SIGN SINCE 690.51 MARKING ON PV MODULE COVERS NEEDED INFORMATION

WARNING: ELECTRICAL SHOCK HAZARD—LINE AND LOAD MAY BE ENERGIZED IN OPEN POSITION

PHOTOVOLTAIC SYSTEM EQUIPPED WITH RAPID SHUTDOWN

PHOTOVOLTAIC POWER SOURCE

*SIGN FOR DC DISCONNECT

PHOTOVOLTAIC SYSTEM DISCONNECT

SOLAR PV SYSTEM DISCONNECT

AC OUTPUT CURRENT | A

SIGN FOR DISTRIBUTION PANELS

THIS PANEL FED BY MULTIPLE SOURCES (UTILITY AND SOLAR)

WARNING: INVERTER OUTPUT CONNECTION; DO NOT RELOCATE THIS OVERCURRENT DEVICE.

PHOTovoltaic System EQUIPPeed WITH RAPID SHUTDOWN

NOTES FOR ONE-LINE STANDARD ELECTRICAL DIAGRAM FOR SINGLE-PHASE PV SYSTEMS

Site Name: ____________________________

Site Address: __________________________

System AC Size: ________________________

Drawn By: ____________________________

Checked By: __________________________

www.solsmart.org
Structural Criteria for Residential Rooftop Solar

Roof Check

Based on the housing stock and enforcement history—reasonable to assume that most dwelling roofs were built to the building code in effect.

Compliance check consists of contractor's visual roof audit checking for modification, unusual sagging, or deterioration.

For AHJs with evidence of structurally deficient housing stock or poor compliance history, the AHJ may elect to add the rafter span check option.
Regional and Site Assumptions—jurisdictions know difficult areas

- Design Wind Speed no greater than 140 mph.
- Structure is not in Wind Exposure D (within 200 yards of the ocean or a large coastal bay).
- If in Wind Exposure C (within 500 yards of large open fields or grasslands), the structure is not on a hill with a grade steeper than 5%.
Array Weight Limits:

(panels + supports)

Toolkit covers both

Photovoltaic Arrays (4 psf max)
Typical: 2.5 to 3.5 psf

Solar Thermal Arrays (5 psf max)
Typical: 3.5 to 4.5 psf
Basic Assumption: Roof is “Code Compliant”

- No second reroof overlays
- Reasonably sound, no decay, no unusual sagging
  = visual inspection

- Rafter Span Table Checks?
  - Pre-1960
    - larger lumber sizes, higher grade
  - Post-1960
    - modern lumber sizes, lower grade
Structural Criteria for Residential Rooftop Solar

"Pre-1960" Construction

- Rough sawn 2x4s at 32" o.c.
- Horizontal span
Structural Criteria for Residential Rooftop Solar

"Carpenter Trusses"

horizontal span
### Table 2. Roof Rafter Maximum Horizontal Span (feet - inches)

<table>
<thead>
<tr>
<th>Assumed Vintage</th>
<th>Nominal Size</th>
<th>Actual Size</th>
<th>Non-Tile Roof</th>
<th>Tile Roof</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>16&quot; o.c.</td>
<td>24&quot; o.c.</td>
</tr>
<tr>
<td>Post-1960</td>
<td>2x4</td>
<td>1½&quot;x3½&quot;</td>
<td>9'-10&quot;</td>
<td>8'-0&quot;</td>
</tr>
<tr>
<td></td>
<td>2x6</td>
<td>1½&quot;x5½&quot;</td>
<td>14'-4&quot;</td>
<td>11'-9&quot;</td>
</tr>
<tr>
<td></td>
<td>2x8</td>
<td>1½&quot;x7¾&quot;</td>
<td>18'-2&quot;</td>
<td>14'-10&quot;</td>
</tr>
<tr>
<td>Pre-1960</td>
<td>2x4</td>
<td>1¾&quot;x3¾&quot;</td>
<td>11'-3&quot;</td>
<td>9'-9&quot;</td>
</tr>
<tr>
<td></td>
<td>2x6</td>
<td>1¾&quot;x5¾&quot;</td>
<td>17'-0&quot;</td>
<td>14'-0&quot;</td>
</tr>
<tr>
<td></td>
<td>2x8</td>
<td>1¾&quot;x7¾&quot;</td>
<td>22'-3&quot;</td>
<td>18'-0&quot;</td>
</tr>
</tbody>
</table>
1. Houses that were built in compliance with building structural codes, can support PV.
2. Single layer of roofing (no second layer of comp).
3. PV modules mounted within 2” and 10” of roof deck.
4. PV array distributed weight less than 4 lb/ft²
5. Typical rafter of 6:12 pitch or less, with supports 48” apart or closer (each anchor row mounted on alternating trusses) meet structural code requirements (represents most of housing stock).
Example 1—7.5kW Central Inverter PV System

PV System Components
PV Modules
  Qty. 30, 285W, American Solar AS285
Inverter
  Qty. 1, 7.5 kW, American Inverter AI-7500
Mounting System
  OmniRack ModMount 5.0; sheathing attached;
House
Form Fill-Out Demonstration

Compliance Document
Standard Plan—Simplified Central Inverter
Structural Criteria—compliant
Sheathing Attached System

Structural Notes:
1. Roof pitch 4:12
2. Roof covering: Single overlay asphalt shingles
3. Black dots represent anchor points
4. Mean roof height less than 30'
5. Roof structure: Truss on 24" centers
6. Roof deck 7/16" OSB
7. Maximum anchor point distance: 48"
8. Dwelling in wind exposure B
9. PV modules mounted 2" above roof covering
10. PV modules certified type 1 for fire purposes
11. OmniRack Mod 5.0 listed class A with type 1 modules

Inverter with supplied combiner and DC disconnect
Existing all-in-one service equipment with 40-AMP PV breaker as AC disconnect

Rooftop J-box under movable PV module to transition exposed PV wire to THWN-2 conductors in ¾" EMT

30 American Solar AS 285 modules in 3 series strings of 10 modules each on existing roof structure

www.solsmart.org
Contractor Name, Address and Phone:
Bill and Ted’s Solar
456 Excellent Drive
San Dimas, CA
800-555-1212

One-Line Standard Electrical Diagram for
Small-Scale, Single-Phase PV Systems

Site Name: John and Jane Homeowner
Site Address: 12 Sunnyside St, Philadelphia, PA
System AC Size: 7.5 KW

Drawn By:
Checked By:

Contractor Name, Address and Phone:
Bill and Ted’s Solar
456 Excellent Drive
San Dimas, CA
800-555-1212

One-Line Standard Electrical Diagram for
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Checked By:

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One-Line Standard Electrical Diagram for
Small-Scale, Single-Phase PV Systems

Site Name: John and Jane Homeowner
Site Address: 12 Sunnyside St, Philadelphia, PA
System AC Size: 7.5 KW

Drawn By:
Checked By:

Contractor Name, Address and Phone:
Bill and Ted’s Solar
456 Excellent Drive
San Dimas, CA
800-555-1212

One-Line Standard Electrical Diagram for
Small-Scale, Single-Phase PV Systems

Site Name: John and Jane Homeowner
Site Address: 12 Sunnyside St, Philadelphia, PA
System AC Size: 7.5 KW

Drawn By:
Checked By:
### PV Module Ratings @ STC (Guide Section ?)

<table>
<thead>
<tr>
<th>Module Make</th>
<th>American Solar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Module Model</td>
<td>AS-285</td>
</tr>
<tr>
<td>Max Power-Point Current (I_{MP})</td>
<td>9.20 A</td>
</tr>
<tr>
<td>Max Power-Point Voltage (V_{MP})</td>
<td>31.3 V</td>
</tr>
<tr>
<td>Open-Circuit Voltage (V_{oc})</td>
<td>39.7 V</td>
</tr>
<tr>
<td>Short-Circuit Current (I_{sc})</td>
<td>9.84 A</td>
</tr>
<tr>
<td>Max Series Fuse (OCPD)</td>
<td>20 A</td>
</tr>
<tr>
<td>Maximum Power (P_{max})</td>
<td>285 W</td>
</tr>
<tr>
<td>Max Voltage (Typ 1000V_{DC})</td>
<td>1000 V</td>
</tr>
</tbody>
</table>

### Notes for Array Circuit Wiring

*Note for Array Circuit Wiring (Guide Section 4 and Appendix E):*

- Lowest Expected Ambient Temperature Based on ASHRAE Minimum Mean Extreme Dry Bulb Temperature for ASHRAE Location Most Similar to Installation Location: Lowest Expected Ambient Temp __-12 °C

### Inverter Ratings (Guide Section 4)

<table>
<thead>
<tr>
<th>Inverter Make</th>
<th>American Inverter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inverter Model</td>
<td>AI-7500</td>
</tr>
<tr>
<td>Max DC Volt Rating</td>
<td>600 V</td>
</tr>
<tr>
<td>Max Power @ 40°C</td>
<td>7500 W</td>
</tr>
<tr>
<td>Nominal AC Voltage</td>
<td>240 V</td>
</tr>
<tr>
<td>Max AC Current</td>
<td>31.25 A</td>
</tr>
<tr>
<td>Max OCPD Rating</td>
<td>40 A</td>
</tr>
</tbody>
</table>

### Notes for Inverter Circuits (Section 42):

1. If utility requires a visible-break switch, does this switch meet the requirement? Yes □ No □ N/A □
2. If generation meter required, does this meter socket meet the requirement? Yes □ No □ N/A □
3. Size inverter output circuit (AC) conductors according to inverter OCPD Ampere Rating. (See Table xxx)
4. Total of ___1___ inverter OCPD(s), one for each inverter, does total supply breakers comply with 120% busbar rule in 705.12(D)? Yes □ No □

### Notes for One-Line Standard Electrical Diagram for Single-Phase PV Systems

<table>
<thead>
<tr>
<th>Contractor Name, Address and Phone:</th>
<th>__________________________</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site Name: ________________________</td>
<td>Site Address: _______________________</td>
</tr>
<tr>
<td>System AC Size: ____________________</td>
<td>________________</td>
</tr>
</tbody>
</table>

**Drawn By:**

**Checked By:**

*Note: Microinverter and AC module systems do not need DC disconnect sign since 690.51 marking on PV module covers needed information*
Example 2— 7.5kW Microinverter PV System

• PV System Components
  – PV Modules
    • Qty. 30, 285W, American Solar AS285
  – Inverters
    • Qty. 30, 250W, American Inverter AI-250
  – Mounting System
    • OmniRack ModMount 4.0; Maximum span 72”;
  – House
    • Roof Pitch 4:12; House built in 1988. Comp shingle roof. [structurally compliant]
Form Fill-Out Demonstration

Compliance Document
Standard Plan—Simplified Microinverter
Structural Criteria (compliant)
Member Attached System

Structural Notes:
1. Roof pitch 4:12
2. Roof covering: Single layer asphalt shingles
3. Black dots represent anchor points
4. Mean roof height less than 30'
5. Roof structure: 2x6 rafters on 24” centers with midspan support—max span 11'6”.
6. Roof deck 7/16” OSB
7. Maximum anchor point horizontal distance: 72”
8. Dwelling in wind exposure B
9. Anchors are 5/16” lag screws with 2.5 embedment in structure
10. Each anchor flashed with “Anchor-Flash” aluminum flashing
11. All module rails run perpendicular to rafters
12. PV modules mounted 5” above roof covering
13. PV modules certified Type 1 for fire purposes
14. Omnirack Mod 3.0 listed Class A with Type 1 modules

50-AMP AC Subpanel with two, 20-AMP PV breakers

Existing all-in-one service equipment with 40-AMP PV breaker as AC disconnect

Roof access

Rooftop J-box under movable PV module to transition exposed PV wire to THWN-2 conductors in 3/4” EMT (typical 3 places)

30 American Solar AS 285 modules each connected to an American inverter AS-250 microinverter in two circuits of 15 microinverters each on existing roof structure
### Equipment Schedule

<table>
<thead>
<tr>
<th>TAG</th>
<th>DESCRIPTION</th>
<th>PART NUMBER</th>
<th>NOTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>PV DC or AC Module</td>
<td>AS 285</td>
<td>AMERICAN SOLAR, QUANTITY - 20 (SEE NOTES SHEET FOR DETAILS)</td>
</tr>
<tr>
<td>2</td>
<td>DC/AC INVERTER (MICRO)</td>
<td>AI-250</td>
<td>250 WATT, SINGLE PHASE (SEE NOTES SHEET FOR DETAILS)</td>
</tr>
<tr>
<td>3</td>
<td>J-BOX (IF USED)</td>
<td>6&quot;x6&quot;x4&quot; NEMA 4, PVC JUNCTION BOX</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>PV ARRAY</td>
<td>N/A</td>
<td>2.20-A AC CIRCUITS WITH 15 MICRO-INVERTERS PER CIRCUIT</td>
</tr>
<tr>
<td>5</td>
<td>AC COMB. PANEL (IF USED)</td>
<td>SD125SL</td>
<td>240VAC, 125-A MAIN LUG PANEL W/ 40-A BREAKER AS MAIN</td>
</tr>
<tr>
<td>6</td>
<td>GEN METER (IF USED)</td>
<td>FORM 2S</td>
<td>4-JAW, 240V CYCLOMETER REGISTER KWH METER IN 100-A BASE</td>
</tr>
<tr>
<td>7</td>
<td>AC DISCONNECT (IF USED)</td>
<td>D222NRB</td>
<td>240VAC, 30-AMP UNFUSED (SEE GUIDE APPENDIX C)</td>
</tr>
<tr>
<td>8</td>
<td>SERVICE PANEL</td>
<td>SD200SL</td>
<td>240VAC, 200-A MAIN, 200-A BUS, 30-A INVERTER OCPD</td>
</tr>
</tbody>
</table>

(SEE NOTE 5 FOR INVERTER OCPDs, ALSO SEE GUIDE SECTION 9)

### Conduit and Conductor Schedule

<table>
<thead>
<tr>
<th>TAG</th>
<th>DESCRIPTION OR CONDUCTOR TYPE</th>
<th>COND.</th>
<th>NUMBER OF</th>
<th>COND.</th>
<th>CONDUIT</th>
<th>CONDUIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>USE-2 or PV WIRE</td>
<td>MFG</td>
<td>6 AWG</td>
<td>MFG Cable</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>2</td>
<td>GEC EGC X ALL THAT APPLY</td>
<td>1 BARE CU</td>
<td>N/A</td>
<td>N/A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>EXTERIOR CABLE LISTED W/ INV.</td>
<td>MFG</td>
<td>12 AWG</td>
<td>MFG Cable</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>4</td>
<td>THWN-2 or XHHW-2 or RHH-2</td>
<td>2-B, 2-R, 2-W</td>
<td>EMT</td>
<td>¾&quot;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>GEC EGC X ALL THAT APPLY</td>
<td>8 AWG</td>
<td>1 GREEN</td>
<td>SAME</td>
<td>SAME</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>NO DC GEC IF 690.35 SYSTEM</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>THWN-2 or XHHW-2 or RHH-2</td>
<td>10 AWG</td>
<td>1-R, 1-B, 1-W</td>
<td>EMT</td>
<td>¾&quot;</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>GEC EGC X ALL THAT APPLY</td>
<td>8 AWG</td>
<td>1 GREEN</td>
<td>SAME</td>
<td>SAME</td>
<td></td>
</tr>
</tbody>
</table>

---

**Contractor Name, Address and Phone:**

Bill and Ted's Solar  
456 Excellent Drive  
San Dimas, CA  
800-555-1212

**Site Name:** John and Jane Homeowner  
**Site Address:** 123 Sunnyside St., Boston, MA  
**System AC Size:** 4.0 KW

**One-Line Standard Electrical Diagram for Micro-Inverter or AC Module PV Systems:**

- **Main Service Panel:**
- **AC Combiner Panel:**
- **AC DISCO:**
- **Grounding Electrode:**
- **Utility Service:**

---

**Drawn By:** Bill  
**Checked By:** Ted  
**Scale:** NTS  
**Date:** SHEET

---

**Equipment Schedule:**

- **Main OCPD:**
- **Inverter OCPD:**
- **Building Grounding Electrode:**

---

**Conduit and Conductor Schedule:**

- **Main Service Panel:**
- **AC Combiner Panel:**
- **AC DISCO:**
- **Grounding Electrode:**
- **Utility Service:**
**Notes for One-Line Standard Electrical Diagram for Single-Phase PV Systems**

**Contractor Name, Address and Phone:**

_________________
_________________
_________________
_________________

**Notes for All Drawings:**

**OCPD = OVERCURRENT PROTECTION DEVICE**

**NATIONAL ELECTRICAL CODE® REFERENCES SHOWN AS (NEC XXX.XX)**

**DC-TO-DC CONVERTER RATINGS (if used)**

<table>
<thead>
<tr>
<th>CONVERTER MAKE</th>
<th>CONVERTER MODEL</th>
<th>MAX CURRENT</th>
<th>MAX VOLTAGE</th>
<th>MAXIMUM POWER (W)</th>
<th>MAX OUTPUT CIRCUIT V (TYP 600VDC)</th>
</tr>
</thead>
</table>

**INVERTER RATINGS (Guide Section 4)**

<table>
<thead>
<tr>
<th>INVERTER MAKE</th>
<th>INVERTER MODEL</th>
<th>MAX DC VOLT RATING</th>
<th>MAX POWER @ 40°C</th>
<th>NOMINAL AC VOLTAGE</th>
<th>MAX AC CURRENT</th>
<th>MAX OCPD RATING</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AI-7500</td>
<td>600 V</td>
<td>7500 W</td>
<td>240 V</td>
<td>31.25 A</td>
<td>40 A</td>
</tr>
</tbody>
</table>

**Notes for Array Circuit Wiring (Guide Section 4 and Appendix E):**

1. **LOWEST EXPECTED AMBIENT TEMPERATURE BASED ON ASHRAE MINIMUM MEAN EXTREME DRY BULB TEMPERATURE FOR ASHRAE LOCATION MOST SIMILAR TO INSTALLATION LOCATION:**

   **LOWEST EXPECTED AMBIENT TEMP ___-12 °C**

2. **NOTE: MICROINVERTER AND AC MODULE SYSTEMS DO NOT NEED DC DISCONNECT SIGN SINCE 690.51 MARKING ON PV MODULE COVERS NEEDED INFORMATION**

3. **Total of __ INVERTER OCPD(s), one for each inverter, does total supply breakers comply with 120% busbar rule in 705.12(D)?**

   **YES ☐ NO ☐ N/A ☐**

4. **Signs—See Guide Section 7**

   ***SIGN FOR DC DISCONNECT**

   **PHOTOVOLTAIC POWER SOURCE**

   **Rated MPP Current (AMP)**

   **Rated MPP Voltage (V)**

   **Max System Voltage (V)**

   **Max Circuit Current (A)**

   **WARNING: ELECTRICAL SHOCK HAZARD—LINE AND LOAD MAY BE ENERGIZED IN OPEN POSITION**

   **SIGN FOR PV SYSTEM DISCONNECT**

   **Solar PV System Disconnect**

   **AC Output Current**

   **Nominal AC Voltage**

   **240 V**

   **Signs for Distribution Panels**

   **THIS PANEL FED BY MULTIPLE SOURCES (UTILITY AND SOLAR)**

   **Sign for NEC 705.12(D)(2)(3)(b) (if used)**

   **WARNING: INVERTER OUTPUT CONNECTION; DO NOT RELOCATE THIS OVERCURRENT DEVICE.**

   **Sign for NEC 690.12 (for roof-mounted systems)**

   **PHOTOVOLTAIC SYSTEM EQUIPPED WITH RAPID SHUTDOWN**

**PV Module Ratings @ STC (Guide Section ?)**

<table>
<thead>
<tr>
<th>MODULE MAKE</th>
<th>AMERICAN SOLAR</th>
<th>MAX POWER-POINT CURRENT (I_{mp})</th>
<th>9.20 Α</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>MAX POWER-POINT VOLTAGE (V_{mp})</td>
<td>31.3 Β</td>
</tr>
<tr>
<td></td>
<td></td>
<td>OPEN-CIRCUIT VOLTAGE (V_{oc})</td>
<td>39.7 Β</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SHORT-CIRCUIT CURRENT (I_{sc})</td>
<td>9.84 Α</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MAX SERIES FUSE (OCPD)</td>
<td>20 Α</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MAXIMUM POWER (P_{max})</td>
<td>285 W</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MAX VOLTAGE (TYP 1000V_{DC})</td>
<td>1000 Β</td>
</tr>
</tbody>
</table>