SOLAR PV STANDARD PLAN - COMPREHENSIVE
Central/String Inverter Systems for One and Two Family Dwellings

SCOPE: Use this plan ONLY for utility-interactive central/string inverter systems not exceeding a total combined system ac inverter output rating of 10kW on the roof of a one- or two-family dwelling or accessory structure. The photovoltaic system must interconnect to a single-phase ac service panel of nominal 120/240Vac with a busbar rating of 225A or less. This plan is not intended for bipolar systems, hybrid systems, or systems that utilize storage batteries, charge controllers, or trackers. Systems must be in compliance with current California Building Standards Codes and local amendments of the authority having jurisdiction (AHJ). Other Articles of the California Electrical Code (CEC) shall apply as specified in 690.3.

MANUFACTURER’S SPECIFICATION SHEETS MUST BE PROVIDED for proposed inverters, modules, combiner/junction boxes, and racking systems. Installation instructions for bonding and grounding equipment shall be provided, and local AHJs may require additional details. Listed and labeled equipment shall be installed and used in accordance with any instructions included in the listing or labeling (CEC 110.3). Equipment intended for use with PV system shall be identified and listed for the application (CEC 690.4(D)).

Job Address: ___________________________ Permit #: __________________

Contractor/ Engineer Name: ___________________________ License # and Class: __________________

Signature: ___________________________ Date: __________ Phone Number: __________________

Total # of Inverters installed: ____________ (If more than one inverter, complete and attach the “Supplemental Calculation Sheets” starting on page 11 & “Load Center Calculations” on page 16 if a new load center is to be used)

Inverter 1 AC Output Power Rating: ____________ Watts
Inverter 2 AC Output Power Rating (if applicable): ____________ Watts
Combined Inverter Output Power Rating: ____________ ≤ 10,000 Watts

Location Ambient Temperatures:

1) Lowest expected ambient temperature for the location (T_L) = _______°C Source: __________________
   Average ambient high temperature = _______ °C Source: __________________

DC Information:

Module Manufacturer: ____________________________ Model: ____________________________

2) Module V_{oc} (from module nameplate): _______Volts
3) Module I_{sc} (from module nameplate): _______Amps

4) Module dc output power under standard test conditions (STC) = _______ Watts (STC)

5) DC Module Layout

Identify each source circuit (string) for inverter 1 shown on the roof plan with a Tag (e.g. A,B,C,...) Number of modules per source circuit for inverter 1

Identify, by tag, which source circuits on the roof are to be paralleled (if none, put N/A)

Combiner 1:

Combiner 2:

Total number of source circuits for inverter 1: ____________
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6) Are DC/DC Converters used? Yes / No If “No,” go to STEP#7. If “Yes,” enter info below.

DC/DC Converter Model #: ________ DC/DC Converter Max DC Input Voltage: ________ Volts
Max DC Output Current: ________ Amps Max DC Output Voltage: ________ Volts
Max # of DC/DC Converters in an Input Circuit: ________ DC/DC Converter Max DC Input Power: ________ Watts
Number of modules per DC/DC Converter ________ × Module DC Power [STEP#4] (_____ Watts) = ________ Watts
Calculated power from the equation above (_____ Watts) ≤ DC/DC Converter Max DC Input Power (_____ Watts)

7) Maximum System DC Voltage – Required for all systems

Max system dc voltage shall not exceed 600 volts, inverter manufacturer’s max input voltage rating (if dc/dc converters are not used) _____ volts, or dc/dc converter max dc input voltage rating (if applicable) _____ volts. If open-circuit voltage \( V_{OC} \) from STEP#2) temperature coefficients (\( \beta \) or \( \epsilon \)) are provided by module manufacturer, use the calculation in Method 1. If \( V_{OC} \) temperature coefficient is not provided by module manufacturer, use the calculation in Method 2.

Module Count: equal to maximum number of modules in ANY source circuit [STEP#5] for systems without dc/dc converters OR equal to number of modules per dc/dc converter [STEP#6] for systems with dc/dc converters

Method 1:
\[
V_{OC} \text{ temperature coefficient } (\beta) = \text{______ } \%/^\circ \text{C} \\
\text{Module Count per source circuit } ____ \times \{V_{OC} + [(T_\text{C}-25) \times (\beta \times V_{OC})/100]\} = \text{______ Volts} \\
\text{If module manufacturer provides a voltage temperature coefficient } (\epsilon) \text{ in mV/^\circ C, use the formula below.} \\
V_{OC} \text{ temperature coefficient } (\epsilon) = \text{______ mV/^\circ C} \\
\text{Module Count per source circuit } ____ \times \{V_{OC} + [(T_\text{C}-25) \times (\epsilon/1000)]\} = \text{______ Volts}
\]

Method 2:

Module Count per source circuit \( ____ \times V_{OC} ____ \times K_T = ____ \text{ Volts,} \)
where \( K_T = ____ \text{ is a correction factor for ambient temperatures below 25^\circ \text{C. See Table 690.7.} \}

8) Maximum System DC Voltage from DC/DC Converters to Inverter – Only required if “Yes” in STEP#6

Maximum system dc voltage shall not exceed 600 volts or inverter manufacturer’s maximum input voltage rating. If using dc/dc converters with fixed source circuit voltage (connected in series), provide the calculation in Method 1. If using dc/dc converters connected in series with an inverter that regulates input dc voltage, provide the calculation in Method 2. If using dc/dc converters with fixed unit voltage (connected in parallel), provide the calculation in Method 3.

Method 1 (similar to Tigo MM-ES and Ampt Converters):
Max # of dc/dc converters in a source circuit [STEP#6] ____ × Max dc output voltage [STEP#6] ______ Volts
= Max system dc voltage _______ Volts
If Max system dc voltage _______ > inverter input voltage rating (_____ Volts) OR 600 Volts, the number of DC/DC converters in the source circuit used for the Method 1 calculation must be reduced to comply with code.

Method 2 (similar to SolarEdge and inverters with Ampt Mode capabilities such as Kaco and Bonfiglioli):
Inverter max input voltage _______ Volts = Max system dc voltage _______ Volts
If Max system dc voltage _______ > 600 Volts, the inverter used for the Method 2 calculation must be changed to comply with code.

Method 3 (similar to Tigo MM-EP and elQ_vBoost):
Max dc output voltage [STEP#6] _______ = Max system dc voltage _______ Volts
If Max system dc voltage _______ > inverter input voltage rating (_____ Volts) OR 600 Volts, the dc/dc converters or inverter used for the Method 3 calculation must be changed to comply with code.

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9) Maximum Source Circuit Current – If dc/dc converters are used, use 9(A). If not, use 9(B).

Calculate the maximum dc short circuit current per source circuit to allow for peak sunlight conditions:

**A.** Largest number of dc/dc converters run in parallel on one source circuit: _____ (= 1 if not run in parallel)

**Max DC Output Current** [STEP#6] _______ × dc/dc converters in parallel _____ = Maximum Circuit Current _____ Amps

**B.** Module \(I_{sc}\) [STEP#3] _______ × 1.25 = Maximum Circuit Current _____ Amps

10) Sizing PV Source Circuit Conductors – Use the LARGER minimum conductor ampacity from Method A or Method B when determining required conductor size.

**Method A:**

Minimum conductor ampacity: Maximum source circuit current [STEP#9] _____ × 1.25 = _____ Amps

**Method B:**

- **# of current-carrying conductors in raceway:** _____
- **Raceway height above the roof:** _____ inches

\[ C_f = _____ \]

\[ C_T = _____ \]

\[ C_f \] is the conduit fill coefficient found by referencing Table 310.15 (B)(3)(a)

\[ C_T \] is a coefficient found by referencing Table 310.15(B)(3)(c) when raceway is mounted above the roof and using that value (if applicable) with Table 310.15(B)(2)a) for highest continuous ambient temperature.

Minimum conductor ampacity: Maximum source circuit current [STEP#9] ______ / (\(C_f \times C_T\)) = _____ Amps

Using the greater current as calculated in **Method A** or **Method B**, use Table 310.15(B)(16) to identify source circuit conductor size (using copper 90°C-rated insulated conductors). The minimum conductor ampacity calculated from **Method A** or **Method B** shall not exceed the ampacity of chosen conductor rated at the lowest temperature rating of any connected termination, conductor, or device (60°C or 75°C).

**Minimum Source Circuit Conductor Size_____ AWG**

(For ungrounded systems, exposed source conductors must be listed “PV Wire,” NOT USE-2, per 2013 CEC 690.35(D))

11) Are PV source circuits combined prior to the inverter? Yes / No

**If No**, use Single Line Diagram 1 and proceed to **STEP#13**.

**If Yes**, use Single Line Diagram 2. Source circuits and output circuits connected to more than one electrical source may be required to have overcurrent protection devices (OCPDs) located so as to provide overcurrent protection from all sources per 690.9(A). Fuses (when used) shall be installed as part of a finger safe fuse holder. Where source circuit OCPD is not required, please put N/A in 11A or 11B as applicable.

**Source circuit OCPD rating:**

**A. Combiner 1:**

(Total number of source circuits) – 1 = ________ (A)

\[ (A) \times (\text{Module } I_{sc}) \times 1.25 = \text{__________ Amps (B)} \]

Modules max OCPD rating (from module nameplate) = ___________ Amps (C)

If (B) > (C), source circuit OCPD is required at the combiner to protect paralleled source circuits

**Source circuit OCPD size________ Amps**

**B. Combiner 2 (If unused, circle N/A):**

N/A

(Total number of source circuits) – 1 = ________ (A)

\[ (A) \times (\text{Module } I_{sc}) \times 1.25 = \text{__________ Amps (B)} \]

Modules max OCPD rating(from module nameplate) = ___________ Amps (C)

If (B) > (C), source circuit OCPD is required at the combiner to protect paralleled source circuits

**Source circuit OCPD size________ Amps**
12) Sizing PV Output Circuit Conductors – If a Combiner box will NOT be used [STEP #11], proceed to STEP #13.

Use the LARGER minimum conductor ampacity from Method A or Method B when determining required conductor size, for both combiners 1 and 2 (when applicable).

Combiner 1:

Method A:
Minimum conductor ampacity: Maximum source circuit current [STEP#9] _____ × 1.25 × Number of parallel source circuits (STEP#5)_____ = _____ Amps

Method B:

# of current-carrying conductors in raceway: ___ Raceway height above the roof: ___ inches (N/A if inapplicable)

\[ C_F = \quad C_T = \quad \]

Minimum conductor ampacity: Maximum circuit current [STEP#9]_____ × Number of parallel source circuits (STEP#5)_____ / (C_F × C_T) = _____ Amps

Using the greater current as calculated in Method A or Method B, use Table 310.15(B)(16) to identify output circuit conductor size (using 90°C-rated copper insulated conductors). The minimum conductor ampacity calculated from Method A or Method B shall not exceed the ampacity of chosen conductor rated at the lowest temperature rating of any connected termination, conductor, or device (60°C or 75°C).

Minimum Output Circuit Conductor Size ______ AWG

Combiner 2 (If unused, circle N/A): N/A

Method A:
Minimum conductor ampacity: Maximum source circuit current [STEP#9] _____ × 1.25 × Number of parallel source circuits (STEP#5)_____ = _____ Amps

Method B:

# of current-carrying conductors in raceway: ___ Raceway height above the roof: ___ inches (N/A if inapplicable)

\[ C_F = \quad C_T = \quad \]

Minimum conductor ampacity: Maximum circuit current [STEP#9]_____ × Number of parallel source circuits (STEP#5)_____ / (C_F × C_T) = _____ Amps

Using the greater current as calculated in Method A or Method B, use 310.15(B)(16) to identify output circuit conductor size (using 90°C-rated copper insulated conductors). The minimum conductor ampacity calculated from Method A or Method B shall not exceed the ampacity of chosen conductor rated at the lowest temperature rating of any connected termination, conductor, or device (60°C or 75°C).

Minimum Output Circuit Conductor Size ______ AWG

13) Inverter DC Disconnect (The dc disconnect shall be grouped with the inverter and inverter ac disconnect)

Does the inverter have an integrated dc disconnect? Yes / No

If yes, proceed to STEP #14.

If No, the external dc disconnect to be installed is rated for _____ Amps (dc) and _____ Volts (dc)

The dc disconnect rating must be greater than or equal to the Max Output Circuit Current [STEP#12 - Method A] or Max Source Circuit Current [STEP #10].
14) Inverter information:
Manufacturer: _____________ Model: ____________ Max. Continuous AC Output Current Rating: ______Amps
Maximum Inverter DC Input Current Rating: _______ Amps

Max Source Circuit Current (STEP#9) _______ Amps × Number of parallel source circuits (STEP#5) _______ = _______ Amps
Calculated current from the line above (_____ Amps) ≤ Max. Inverter Short Circuit Current Rating (_____ Amps)

Max. Inverter Short Circuit Current Rating = 1.5 (per UL 1741 testing standard) × Max. Inverter DC Input Current Rating, if max short circuit current rating is not available from manufacturer.

Integrated DC Arc-Fault Circuit Protection? Yes / No (If “No” is selected, provide arc-fault protection per 690.11)

AC Information:
15) Sizing Inverter Output Circuit Conductors and OCPD: Use the LARGER conductor ampacity from Method A or Method B when determining conductor size. Use Method A to determine Inverter Output OCPD rating.

Method A:
Minimum conductor ampacity: Max AC Output Current Rating[STEP#14] _______ × 1.25 = _______ Amps

Method B:
# of current-carrying conductors in raceway: _____ Raceway height above the roof: ______ inches

\[ C_F = _____ \]

\[ C_T = _____ \]

\[ C_F \] is the conduit fill coefficient found by referencing Table 310.15 (B)(3)(a)
\[ C_T \] is a coefficient dependent on the highest continuous ambient temperature and raceway height above roof (if applicable) and is found by referencing Tables 310.15(B)(2)(a), and if part of the raceway is installed on the roof, use 310.15(B)(3)(c) as well.

Minimum conductor ampacity: Maximum ac output current rating [STEP#14] _______ / \( C_F \times C_T \) = _______ Amps

Minimum Conductor Size: _______ AWG

Using the greater current as calculated in Method A or Method B, use Table 310.15(B)(16) to identify ac circuit conductor size. The minimum conductor ampacity shall not exceed the ampacity of chosen conductor rated at the lowest temperature rating of any connected termination, conductor, or device (60°C or 75°C).

Size the inverter output OCPD based on the value calculated in Method A. Where the figure is between two standard values of fuse/breaker sizes (see 240.6(A)), the next higher size may be used (see 240.4(B)). The OCPD’s rating may not exceed the conductor ampacity or the inverter manufacturer’s max OCPD rating for the inverter.

Inverter Output Max OCPD rating = _______ Amps
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16) **Point of Connection to Utility:** One of the following methods of interconnection must be utilized.

A. Supply Side Connection: Yes / No
Check with your local jurisdiction to determine if this connection is allowed.
Supply side connections shall only be permitted where the service panel is listed for the purpose. The sum of the ratings of all overcurrent devices (STEP #15 or 21) connected to power production sources shall not exceed the rating of the service. The connection shall not compromise listing or integrity of any equipment.

B. Load Side Connection: Yes / No
Is the PV OCPD positioned at the opposite end from input feeder location or main OCPD location? Yes / No
(If No to the statement above, the sum of OCPD(s) supplying the panel cannot exceed 100% of the busbar rating; circle 100% as the multiplier in calculation. Otherwise, circle 120% and use that as the multiplier)
Per 705.12(D)(2): \[Inverter output OCPD size [STEP #15 or S21] + Main OCPD Size]\[Bus size \times (100\% or 120\%)]

| Maximum Combined Supply OCPDs Based on Busbar Rating (Amps) per CEC 705.12(D)(2) |
|-------------------------|----------------|----------------|----------------|--------------|----------------|----------------|----------------|
| Busbar Rating           | 100            | 125            | 125            | 200          | 200           | 200            | 225            | 225          |
| Main OCPD               | 100            | 100            | 125            | 150          | 175           | 200            | 200            | 225          |
| Max Combined PV System OCPDs at 120% of Busbar Rating | 20 | 50 | 25 | 60* | 60* | 40 | 60* | 60* | 45 |
| Max Combined PV System OCPDs at 100% of Busbar Rating | 0 | 25 | 0 | 50 | 25 | 0 | 50 | 25 | 0 |

*This value has been lowered to 60A from the calculated value to reflect 10kW ac size maximum.
All upstream panelboard busbar ratings must also comply with 705.12(D)(2). If the main breaker is reduced, a load calculation per Article 220 must accompany the Standard Plans to show that the reduction is allowed.

17) **Per Section 690.53,** a permanent label for the dc power source shall be installed at the PV dc disconnecting means that shall indicate the following:
(a) Rated maximum power-point current (I_{mpp} from the module nameplate):
\[I_{mpp} \times \{ 1 \text{ (one source circuit) OR } \# \text{ (source circuits in parallel [STEP#5] } \} \text{ Amps}\]
(b) Rated maximum power-point voltage (V_{mpp} from the module nameplate):
\[V_{mpp} \times \{ \# \text{ of modules per source circuit [STEP#5] } \} \text{ Volts}\]
(c) Short circuit current of the PV system (=STEP#9, if no strings are combined prior to inverter)
Maximum source circuit current (STEP#9) \times \text{ (Number of strings) Amps}\]
(d) Maximum system voltage [STEP#7 or #8 for systems with dc/dc converters]
\[-\text{value calculated in STEP#8.}\]

If using dc/dc converters in series (fixed source circuit voltage) with or without an input voltage-regulating inverter, the value for (a) shall be the value for (c), and (b) shall not be applicable. If using dc/dc converters in parallel (fixed unit voltage), the value for (b) shall be the value for (d), and (a) shall not be applicable.

18) **Per Section 690.54,** a permanent label shall be installed at an accessible location at the PV ac disconnecting means that shall indicate the following:
(a) Rated ac output current:
\[\text{AC Output Inverter 1 [STEP#14]} \text{ Amps}\]
\[\text{AC Output Inverter 2 [If Applicable]} \text{ Amps}\]
\[\text{Rated ac output current (sum of above values)}: \text{ Amps}\]
(b) Nominal operating ac voltage:
\[\text{Volts}\]
### 19) Grounding and Bonding:

Check one of the boxes for whether system is grounded or ungrounded:

- ☐ GROUNDED (SEE A & B)
- ☐ UNGROUNDED (SEE A & C)

#### A. All Systems:
Modules and racking must be bonded by a method listed to the respective UL standard and recognized by the respective equipment manufacturers. Bonding method is subject to AHJ approval. DC and ac equipment grounding conductor (EGC) shall be sized based on source and output circuit conductors per 690.45 using Table 250.122. Where exposed to physical damage, it is required to be #6 AWG copper per 690.46. A dc EGC is required for both grounded and ungrounded systems. If an existing premises grounding electrode system is not present, a new grounding electrode system must be established per 250.53.

Where supplementary grounding electrodes are installed, a bonding jumper to the existing grounding electrode must be installed. Bonding jumpers must be sized to the larger grounding conductor that it is bonded to (CEC 250.58).

#### B. Grounded Systems:
The dc grounding electrode conductor (GEC) from the inverter terminal must be unbroken or irreversibly spliced and sized minimum #8 AWG copper per article 250.166. The dc GEC from the inverter terminal to the existing grounding electrode system must tie to the existing grounding electrode or be bonded to the existing ac GEC using an irreversible means, per 250.64(C)(1).

A combined dc GEC and ac EGC may be run from the inverter dc grounding terminal to the grounding busbar in the associated ac equipment. This combined grounding conductor must be sized to the larger of the GEC and EGC sizes, with the bonding requirements of EGCs and remaining continuous as a GEC, per 690.47(C)(3).

#### C. Ungrounded Systems:
A dc GEC shall not be required from the inverter dc grounding terminal to the building grounding electrode system. The EGC shall run from the inverter to the grounding busbar in the associated ac equipment, sized per 690.45, using Table 250.122. Ungrounded conductors must be identified per 210.5(C). White-finished conductors are not permitted.
Markings

CEC Articles 690 and 705 and CRC Section R331 require the following labels or markings be installed at these components of the photovoltaic system:

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

CEC 705.12(D)(7)
[Not required if panelboard is rated not less than sum of ampere ratings of all overcurrent devices supplying it]

**WARNING**
ELECTRIC SHOCK HAZARD. THE DC CONDUCTORS OF THIS PHOTOVOLTAIC SYSTEM ARE UNGROUNDED AND MAY BE ENERGIZED

CEC 690.35(F)
[Only required for ungrounded systems]

**WARNING**
PHOTOVOLTAIC POWER SOURCE

CRC R331.2 and CFC 605.11.1
[Marked on junction/combiner boxes and conduit every 10']

**WARNING**
DUAL POWER SOURCES
SECOND SOURCE IS PHOTOVOLTAIC SYSTEM
RATED AC OUTPUT CURRENT- ____AMPS
AC NORMAL OPERATING VOLTAGE ___VOLTS

CEC 690.54 & CEC 705.12(D)(4)
[SEE STEP #18, PAGE 6]

**WARNING**
PV SYSTEM AC DISCONNECT
RATED AC OUTPUT CURRENT - ____AMPS
AC NORMAL OPERATING VOLTAGE ___VOLTS

CEC 690.54
[See STEP #18, PAGE 6]

**WARNING**
ELECTRIC SHOCK HAZARD
IF A GROUND FAULT IS INDICATED, NORMALLY GROUNDED CONDUCTORS MAY BE UNGROUNDED AND ENERGIZED

CEC 690.5(C)
[Normally already present on listed inverters]

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

CEC 690.17

**WARNING**
PHOTOVOLTAIC POWER SOURCE
PV SYSTEM DC DISCONNECT
RATED MAX POWER-POINT CURRENT- ___ADC
RATED MAX POWER-POINT VOLTAGE- ___VDC
SHORT CIRCUIT CURRENT- ___ADC
MAXIMUM SYSTEM VOLTAGE- ___VDC

CEC 690.53
[See STEP #17, PAGE 6]
[See STEP #16, PAGE 12 if using two inverters]

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Informational note: ANSI Z535.4 provides guidelines for the design of safety signs and labels for application to products. A phenolic plaque with contrasting colors between the text and background would meet the intent of the code for permanency. No type size is specified, but 20 point (3/8") should be considered the minimum.

CEC 705.12 requires a permanent plaque or directory denoting all electric power sources on or in the premises.
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### DESCRIPTION

**SOLAR PV MODULE / STRING**

- DC/DC CONVERTERS INSTALLED? **YES / NO** (IF YES, STEPS 6 & 8 REQUIRED)

**SOURCE CIRCUIT JUNCTION BOX INSTALLED?** **YES / NO**

**SEPARATE DC DISCONNECT INSTALLED?** **YES / NO**

**INTERNAL INVERTER DC DISCONNECT** **YES / NO**

**CENTRAL INVERTER** **YES / NO**

**LOAD CENTER INSTALLED?** **YES / NO**

**PV PRODUCTION METER INSTALLED?** **YES / NO**

- **SEPARATE AC DISCONNECT INSTALLED?** **YES / NO**

- **INTERNAL INVERTER DC DISCONNECT** **YES / NO**

- **CENTRAL INVERTER LOAD CENTER INSTALLED?** **YES / NO**

- **PV PRODUCTION METER INSTALLED?** **YES / NO**

- **SEPARATE AC DISCONNECT INSTALLED?** **YES / NO**

- **CONNECT TO INVERTER #2** (USE LINE DIAGRAM 2)

**TAG DESCRIPTION AND CONDUCTOR TYPE CONDUCTOR SIZE NUMBER OF CONDUCTORS CONDUIT/CABLE TYPE CONDUIT SIZE**

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* Consult with your local AHJ and/or Utility

### SINGLE-LINE DIAGRAM #1 – NO STRINGS COMBINED PRIOR TO INVERTER

- **CHECK A BOX FOR WHETHER SYSTEM IS GROUNDED OR UNGROUNDED:**
  - **GROUNDED (INCLUDE GEC)**
  - **UNGROUNDED**

**FOR UNGROUNDED SYSTEMS:**
- **DC OCPD MUST DISCONNECT BOTH CONDUCTORS OF EACH SOURCE CIRCUIT**
- **UNGROUNDED CONDUCTORS MUST BE IDENTIFIED PER 210.5(C). WHITE-FINISHED CONDUCTORS ARE NOT PERMITTED.**

- **PARALLEL DC/DC CONVERTERS ON ONE SOURCE CIRCUIT (FIXED UNIT VOLTAGE DC/DC CONVERTERS)**
- **DC/DC CONVERTERS ARE ALL RUN IN SERIES (FIXED SOURCE CIRCUIT VOLTAGE DC/DC CONVERTERS)**

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**ENTER "N/A" WHERE SUITABLE FOR WHEN NOT USING CONDUIT OR CABLE AS PERMITTED BY CODE**

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<td>E</td>
<td>EGC/GEC:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Consult with your local AHJ and/or Utility

**SINGLE-LINE DIAGRAM #2 – COMBINING STRINGS PRIOR TO INVERTER**

CHECK A BOX FOR WHETHER SYSTEM IS GROUNDED OR UNGROUNDED:
- GROUNDED (INCLUDE GEC)
- UNGROUNDED

FOR UNGROUNDED SYSTEMS:
- DC OCPD MUST DISCONNECT BOTH CONDUCTORS OF EACH SOURCE CIRCUIT
- UNGROUNDED CONDUCTORS MUST BE IDENTIFIED PER 210.5(C). WHITE-FINISHED CONDUCTORS ARE NOT PERMITTED.

**CONDUCTOR/CONDUIT SCHEDULE**

**CONDUCTOR/CONDUIT SCHEDULE**

**IF DC/DC CONVERTERS ARE USED, THEY ARE RUN IN SERIES (FIXED SOURCE CIRCUIT VOLTAGE DC/DC CONVERTERS)**
SOLAR PV STANDARD PLAN - COMPREHENSIVE
Central/String Inverter Systems for One and Two Family Dwellings
Supplemental Calculation Sheets for Inverter #2:
(Only include if no more than one additional inverter is used)

DC Information:

<table>
<thead>
<tr>
<th>Module Manufacturer: ________________</th>
<th>Model: ________________</th>
</tr>
</thead>
<tbody>
<tr>
<td>S2) Module $V_{oc}$ (from module nameplate): _____ Volts</td>
<td>S3) Module $I_{sc}$ (from module nameplate): _____ Amps</td>
</tr>
<tr>
<td>S4) Module dc output power under standard test conditions (STC) = ________ Watts (STC)</td>
<td></td>
</tr>
<tr>
<td>S5) DC Module Layout</td>
<td></td>
</tr>
<tr>
<td>Identify each source circuit (string) for inverter 2 shown on the roof plan with a Tag (e.g. A,B,C,...)</td>
<td>Number of modules per source circuit for inverter 2</td>
</tr>
<tr>
<td>Identify, by tag, which source circuits on the roof are to be paralleled (if none, put N/A)</td>
<td></td>
</tr>
<tr>
<td>Combiner 1:</td>
<td>Combiner 2:</td>
</tr>
<tr>
<td>Total number of source circuits for inverter 2:</td>
<td></td>
</tr>
</tbody>
</table>

S6) Are DC/DC Converters used? Yes / No | If “No,” go to STEP#S7. If “Yes,” enter info below. |
| DC/DC Converter Model #: __________ | DC/DC Converter Max DC Input Voltage: _____ Volts |
| Max DC Output Current: _______ Amps | Max DC Output Voltage: _______ Volts |
| Max # of DC/DC Converters in an Input Circuit: _______ | DC/DC Converter Max DC Input Power: _______ Watts |
| Number of modules per DC/DC Converter _______ × Module DC Power [STEP#S4] (_____Watts) = _______ Watts |
| Calculated power from the equation above (_____Watts) ≤ DC/DC Converter Max DC Input Power (_______Watts) |

S7) Maximum System DC Voltage – Required for all systems

Max system dc voltage shall not exceed 600 volts, inverter manufacturer’s max input voltage rating (if dc/dc converters are not used) _____ volts, or dc/dc converter max dc input voltage rating (if applicable) _____ volts. If open-circuit voltage ($V_{oc}$ from STEP#S2) temperature coefficients ($\beta$ or $\varepsilon$) are provided by module manufacturer, use the calculation in Method 1. If $V_{oc}$ temperature coefficient is not provided by module manufacturer, use the calculation in Method 2.

Module Count: equal to maximum number of modules in ANY source circuit [STEP#S5] for systems without dc/dc converters OR equal to number of modules per dc/dc converter [STEP#S6] for systems with dc/dc converters

Method 1:
$V_{oc}$ temperature coefficient ($\beta$)= _____ %/°C
Module Count per source circuit ______ × $\{V_{oc} + [(T_{L}-25) \times (\beta \times V_{oc})/100]\} = _______ Volts

If module manufacturer provides a voltage temperature coefficient ($\varepsilon$) in mV/°C, use the formula below.
$V_{oc}$ temperature coefficient ($\varepsilon$)= _____ mV/°C
Module Count per source circuit ______ × $\{V_{oc} + [(T_{L}-25) \times (\varepsilon/1000)]\} = _______ Volts

Method 2:
Module Count per source circuit ______ × $V_{oc}$ ______ × $K_{f}$ = _______ Volts,
where $K_{f}$= _______ is a correction factor for ambient temperatures below 25°C. See Table 690.7.
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S8) Maximum System DC Voltage from DC/DC Converters to Inverter – Only required if “Yes” in STEP#S6

Maximum system dc voltage shall not exceed 600 volts or inverter manufacturer’s maximum input voltage rating. If using dc/dc converters with fixed source circuit voltage (connected in series), provide the calculation in Method 1. If using dc/dc converters connected in series with an inverter that regulates input dc voltage, provide the calculation in Method 2. If using dc/dc converters with fixed unit voltage (connected in parallel), provide the calculation in Method 3.

Method 1:
Max # of dc/dc converters in a source circuit [STEP#S6] _____ × Max dc output voltage [STEP#S6] _____ Volts
= Max system dc voltage _________ Volts
If Max system dc voltage _________ > inverter input voltage rating (___ Volts) OR 600 Volts, the number of DC/DC converters in the source circuit used for the Method 1 calculation must be reduced to comply with code.

Method 2:
Inverter max input voltage _______ Volts = Max system dc voltage _________ Volts
If Max system dc voltage _________ > 600 Volts, the inverter used for the Method 2 calculation must be changed to comply with code.

Method 3:
Max dc output voltage [STEP#S6] _______ = Max system dc voltage _________ Volts
If Max system dc voltage _________ > inverter input voltage rating (___ Volts) OR 600 Volts, the dc/dc converters or inverter used for the Method 3 calculation must be changed to comply with code.

S9) Maximum Source Circuit Current – If dc/dc converters are used, use 9(A). If not, use 9(B).

Calculate the maximum dc short circuit current per source circuit to allow for peak sunlight conditions:

A. Largest number of dc/dc converters run in parallel on one source circuit: _____ ( = 1 if not run in parallel)

Max DC Output Current [STEP#S6] _____ × dc/dc converters in parallel _____ = Maximum Circuit Current _____ Amps

B. Module Isc [STEP#S3] _______ × 1.25 = Maximum Circuit Current _____ Amps

S10) Sizing PV Source Circuit Conductors – Use the LARGER minimum conductor ampacity from Method A or Method B when determining required conductor size.

Method A:
Minimum conductor ampacity: Maximum source circuit current [STEP#S9] _____ × 1.25 = _____ Amps

Method B:
# of current-carrying conductors in raceway: _____ Raceway height above the roof: _____ inches
Cf = _____ Cf is the conduit fill coefficient found by referencing Table 310.15 (B)(3)(a)
Cf = _____ Cf is a coefficient found by referencing Table 310.15(B)(3)(c) when raceway is mounted above the roof and using that value (if applicable) with Table 310.15(B)(2)(a) for highest continuous ambient temperature.
Minimum conductor ampacity: Maximum source circuit current [STEP#S9]_____ / (Cf × Cf) = _____ Amps

Using the greater current as calculated in Method A or Method B, use Table 310.15(B)(16) to identify source circuit conductor size (using copper 90°C-rated insulated conductors). The minimum conductor ampacity calculated from Method A or Method B shall not exceed the ampacity of chosen conductor rated at the lowest temperature rating of any connected termination, conductor, or device (60°C or 75°C).

Minimum Source Circuit Conductor Size ______ AWG
(For ungrounded systems, exposed source conductors must be listed “PV Wire,” NOT USE-2, per 2013 CEC 690.35(D))
S11) Are PV source circuits combined prior to the inverter? Yes / No

If No, use Single Line Diagram 3 and proceed to STEP#S13.

If Yes, use Single Line Diagram 4. Source circuits and output circuits connected to more than one electrical source may be required to have overcurrent protection devices (OCPDs) located so as to provide overcurrent protection from all sources per 690.9(A). Fuses (when used) shall be installed as part of a finger safe fuse holder. Where source circuit OCPD is not required, please put N/A in S11A or S11B as applicable.

Source circuit OCPD rating:

A. Combiner 1:

(Total number of source circuits) − 1 = __________ (A)

A) * (Module I_sc)* 1.25 = _______________ Amps (B)

Modules max OCPD rating (from module nameplate) = _______________ Amps (C)

If (B) > (C), source circuit OCPD is required at the combiner to protect paralleled source circuits

Source circuit OCPD size________ Amps

B. Combiner 2 (If unused, circle N/A): N/A

(Total number of source circuits) − 1 = __________ (A)

A) * (Module I_sc)* 1.25 = _______________ Amps (B)

Modules max OCPD rating (from module nameplate) = _______________ Amps (C)

If (B) > (C), source circuit OCPD is required at the combiner to protect paralleled source circuits

Source circuit OCPD size________ Amps
S12) Sizing PV Output Circuit Conductors – If a Combiner box will NOT be used [STEP#S11], proceed to STEP#S13.
Use the LARGER minimum conductor ampacity from Method A or Method B when determining required conductor size, for both combiners 1 and 2 (when applicable).

Combiner 1:
Method A:
Minimum conductor ampacity: Maximum source circuit current [STEP#S9] _____ × 1.25 × Number of parallel source circuits (STEP#S5)_____ = _____ Amps

Method B:
# of current-carrying conductors in raceway: ___Raceway height above the roof: ___ inches (N/A if inapplicable)
C_F = ____  C_T = ____
Minimum conductor ampacity: Maximum circuit current [STEP#S9]_____ × Number of parallel source circuits (STEP#S5)__ / (C_F × C_T) = _____ Amps

Using the greater current as calculated in Method A or Method B, use Table 310.15(B)(16) to identify output circuit conductor size (using 90°C-rated copper insulated conductors). The minimum conductor ampacity calculated from Method A or Method B shall not exceed the ampacity of chosen conductor rated at the lowest temperature rating of any connected termination, conductor, or device (60°C or 75°C).

Minimum Output Circuit Conductor Size ______ AWG

Combiner 2 (If unused, circle N/A): N/A
Method A:
Minimum conductor ampacity: Maximum source circuit current [STEP#S9] _____ × 1.25 × Number of parallel source circuits (STEP#S5)_____ = _____ Amps

Method B:
# of current-carrying conductors in raceway: ___Raceway height above the roof: ___ inches (N/A if inapplicable)
C_F = ____  C_T = ____
Minimum conductor ampacity: Maximum circuit current [STEP#S9]_____ × Number of parallel source circuits (STEP#S5)__ / (C_F × C_T) = _____ Amps

Using the greater current as calculated in Method A or Method B, use 310.15(B)(16) to identify output circuit conductor size (using 90°C-rated copper insulated conductors). The minimum conductor ampacity calculated from Method A or Method B shall not exceed the ampacity of chosen conductor rated at the lowest temperature rating of any connected termination, conductor, or device (60°C or 75°C).

Minimum Output Circuit Conductor Size ______ AWG

S13) Inverter DC Disconnect (The dc disconnect shall be grouped with the inverter and inverter ac disconnect)
Does the inverter have an integrated dc disconnect? Yes / No
If yes, proceed to STEP#S14.
If no, the external dc disconnect to be installed is rated for ______ Amps (dc) and ______ Volts (dc)
The dc disconnect rating must be greater than or equal to the Max Output Circuit Current [STEP#S12 – Method A] or Max Source Circuit Current [STEP #S10].
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AC Information:

S14) Inverter information:
Manufacturer: _____________ Model: ______________ Max. Continuous AC Output Current Rating: ______Amps
Maximum Inverter DC Input Current Rating: _______Amps

Max Source Circuit Current (STEP#S9) _____ Amps × Number of parallel source circuits (STEP#S5) _____ = _____Amps
Calculated current from the line above (_____ Amps) ≤ Max. Inverter Short Circuit Current Rating (_____ Amps)

Max. Inverter Short Circuit Current Rating = 1.5 (per UL 1741 testing standard) × Max. Inverter DC Input Current Rating, if max short circuit current rating is not available from manufacturer.

Integrated DC Arc-Fault Circuit Protection? Yes / No (If “No” is selected, provide arc-fault protection per 690.11)

S15) Sizing Inverter Output Circuit Conductors and OCPD: Use the LARGER conductor ampacity from Method A or Method B when determining conductor size. Use Method A to determine Inverter Output OCPD rating.

Method A:
Minimum conductor ampacity: Max AC Output Current Rating[STEP#S14] _____ × 1.25 = _____Amps

Method B:
# of current-carrying conductors in raceway: _____ Raceway height above the roof: _____ inches
C_F = ____ C_T is the conduit fill coefficient found by referencing Table 310.15 (B)(3)(a)
C_T = ____ C_T is a coefficient dependent on the highest continuous ambient temperature and raceway height above roof (if applicable) and is found by referencing Tables 310.15(B)(2)(a), and if part of the raceway is installed on the roof, use 310.15(B)(3)(c) as well.
Minimum conductor ampacity: Maximum ac output current rating [STEP#S14]_____ / (C_F × C_T) = ____ Amps

Minimum Conductor Size: ______ AWG

Using the greater current as calculated in Method A or Method B, use Table 310.15(B)(16) to identify ac circuit conductor size. The minimum conductor ampacity shall not exceed the ampacity of chosen conductor rated at the lowest temperature rating of any connected termination, conductor, or device (60°C or 75°C).

Size the inverter output OCPD based on the value calculated in Method A. Where the figure is between two standard values of fuse/breaker sizes (see 240.6(A)), the next higher size may be used (see 240.4(B)). The OCPD’s rating may not exceed the conductor ampacity or the inverter manufacturer’s max OCPD rating for the inverter.

Inverter Output Max OCPD rating = ____ Amps

S16) Per Section 690.53, a permanent label for the dc power source shall be installed at the PV dc disconnecting means that shall indicate the following:
(a) Rated maximum power-point current (I_{mpp} from the module nameplate):
I_{mpp} _____ × (1 (one source circuit) OR _____ (# source circuits in parallel [STEP#S5]) _______ Amps

(b) Rated maximum power-point voltage (V_{mpp} from the module nameplate):
V_{mpp}_____ × _________ { Max # of modules per source circuit [STEP#S5] } _________ Volts

(c) Short circuit current of the PV system (= STEP#S9, if no strings are combined prior to inverter)
Maximum source circuit current (STEP#S9) _____ × _______ (Number of strings) _______ Amps

(d) Maximum system voltage [STEP#7 or #8 for systems with dc/dc converters]
[For systems with dc/dc converters, this label’s maximum system voltage value shall be the larger of the following: the lowest value of the inverter’s input voltage range OR the value calculated in STEP#8.]
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Load Center Calculations:
(Only include if a load center will be installed)

<table>
<thead>
<tr>
<th>S20) Maximum output for each inverter:</th>
</tr>
</thead>
<tbody>
<tr>
<td>From supplemental calculation sheet used, list the calculated maximum ac output value [STEP#S14]:</td>
</tr>
<tr>
<td>Inverter #1 Maximum ac output: _____Amps</td>
</tr>
<tr>
<td>Inverter #2 Maximum ac output: _____Amps</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>S21) Load Center Output:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calculate the sum of the maximum ac outputs from [STEP#S20].</td>
</tr>
<tr>
<td>Total inverter currents connected to load center = _____Amps</td>
</tr>
</tbody>
</table>

Use the LARGER conductor ampacity from Method A or Method B when determining conductor size. Use Method A to determine Inverter Output OCPD rating.

**Method A:**
Minimum conductor ampacity: Max AC Output Current Rating [STEP#S21] _______ × 1.25 = _____ Amps

**Method B:**
# of current-carrying conductors in raceway: _____ Raceway height above the roof: _____ inches

CF = ____ CT = ____
CT is a coefficient dependent on the highest continuous ambient temperature and raceway height above roof (if applicable) and is found by referencing Tables 310.15(B)(3)(c) and 310.15(B)(2)(a)

Minimum conductor ampacity: Maximum ac output current rating [STEP#S21] ______ / (CF × CT) = _____ Amps

Minimum Conductor Size: ______ AWG

Using the greater ampacity as calculated in Method A or Method B, use Table 310.15(B)(16) to identify ac circuit conductor size. The conductor ampacity shall not exceed the ampacity of chosen conductor rated at the lowest temperature rating of any connected termination, conductor, or device (60°C or 75°C).

Size the OCPD based on the value calculated in Method A. Where the figure is between two standard values of fuse/breaker sizes (see 240.6(A)), the next higher size may be used provided the conductors are sufficiently sized.

**Overcurrent Protection Device:** _____Amps

**Load center busbar rating:** _____Amps

The sum of the ampere ratings of overcurrent devices in circuits supplying power to a busbar or conductor shall not exceed 120 percent of the rating of the busbar or conductor.
**SOLAR PV STANDARD PLAN - COMPREHENSIVE**

Central/String Inverter Systems for One and Two Family Dwellings

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<table>
<thead>
<tr>
<th>TAG</th>
<th>DESCRIPTION</th>
<th>DC/DC CONVERTERS INSTALLED?</th>
<th>YES / NO</th>
<th>SOURCE CIRCUIT JUNCTION BOX INSTALLED?</th>
<th>YES / NO</th>
<th>SEPARATE DC DISCONNECT INSTALLED?</th>
<th>YES / NO</th>
<th>INTERNAL INVERTER DC DISCONNECT</th>
<th>YES / NO</th>
<th><strong>SEPARATE AC DISCONNECT INSTALLED</strong></th>
<th>YES / NO</th>
<th>TO LOAD CENTER ON LINE DIAGRAM 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>SOLAR PV MODULE / STRING</td>
<td>2</td>
<td>YES</td>
<td>3</td>
<td>YES</td>
<td>4</td>
<td>YES</td>
<td>5</td>
<td>YES</td>
<td>6</td>
<td>YES</td>
<td>7</td>
</tr>
</tbody>
</table>

* Consult with your local AHJ and/or Utility

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**SINGLE-LINE DIAGRAM #3 – ADDITIONAL INVERTER FOR DIAGRAM #1**

**INVERTER # 2**

CHECK A BOX FOR WHETHER SYSTEM IS GROUNDED OR UNGROUNDED:

- [ ] GROUNDED (INCLUDE GEC)
- [ ] UNGROUNDED

FOR UNGROUNDED SYSTEMS:

- DC OCPD MUST DISCONNECT BOTH CONDUCTORS OF EACH SOURCE CIRCUIT
- UNGROUNDED CONDUCTORS MUST BE IDENTIFIED PER 210.5(C). WHITE-FINISHED CONDUCTORS ARE NOT PERMITTED.

---

**CONDUCTOR/CONDUIT SCHEDULE**

<table>
<thead>
<tr>
<th>TAG</th>
<th>DESCRIPTION AND CONDUCTOR TYPE</th>
<th>CONDUCTOR SIZE</th>
<th>NUMBER OF CONDUCTORS</th>
<th>CONDUIT/CABLE TYPE</th>
<th>CONDUIT SIZE</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>USE-2 OR PV-WIRE</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>EGC/GEC:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>EGC/GEC:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

ENTER "N/A" WHERE SUITABLE FOR WHEN NOT USING CONDUIT OR CABLE AS PERMITTED BY CODE

---

**IF DC/DC CONVERTERS ARE USED, CHECK THE BOX BELOW THE CORRESPONDING CONFIGURATION**

- PARALLEL DC/DC CONVERTERS ON ONE SOURCE CIRCUIT (FIXED UNIT VOLTAGE DC/DC CONVERTERS)
- DC/DC CONVERTERS ARE ALL RUN IN SERIES (FIXED SOURCE CIRCUIT VOLTAGE DC/DC CONVERTERS)
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DESCRIPTION
SOLAR PV MODULE / STRING
DC/DC CONVERTERS INSTALLED? YES / NO (IF YES, STEPS 6 & 8 REQUIRED)
SOURCE CIRCUIT JUNCTION BOX INSTALLED? YES / NO
COMBINER BOX (STEPS 11 & 12 REQUIRED)
SEPARATE DC DISCONNECT INSTALLED? YES / NO
INTERNAL INVERTER DC DISCONNECT: YES / NO
SEPARATE AC DISCONNECT INSTALLED? YES / NO
CENTRAL INVERTER

* SEPARATE AC DISCONNECT INSTALLED? YES / NO
TO LOAD CENTER ON LINE DIAGRAM

CHECK A BOX FOR WHETHER SYSTEM IS GROUNDED OR UNGROUNDED:
GROUNDED (INCLUDE GEC)
UNGROUNDED

FOR UNGROUNDED SYSTEMS:
- DC OCPD MUST DISCONNECT BOTH CONDUCTORS OF EACH SOURCE CIRCUIT
- UNGROUNDED CONDUCTORS MUST BE IDENTIFIED PER 210.5(C). WHITE-FINISHED CONDUCTORS ARE NOT PERMITTED.

* Consult with your local AHJ and/or Utility

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TAG CONDUCTOR/CONDUIT SCHEDULE
1 USE-2 OR PV-WIRE
   EGC/GEC
B1 USE-2 OR PV-WIRE
   EGC/GEC
C1 USE-2 OR PV-WIRE
   EGC/GEC
D USE-2 OR PV-WIRE
   EGC/GEC

TAG DESCRIPTION AND CONDUCTOR TYPE
1 SOLAR PV MODULE / STRING
2 DC/DC CONVERTERS INSTALLED
3 SOURCE CIRCUIT JUNCTION BOX INSTALLED
4 COMBINER BOX
5 SEPARATE DC DISCONNECT INSTALLED
6 INTERNAL INVERTER DC DISCONNECT
7 CENTRAL INVERTER
8 SEPARATE AC DISCONNECT INSTALLED
9 TO LOAD CENTER ON LINE DIAGRAM

IF DC/DC CONVERTERS ARE USED, THEY ARE RUN IN SERIES (FIXED SOURCE CIRCUIT VOLTAGE DC/DC CONVERTERS)