***PV TOOLKIT DOCUMENT #3***

Your City logo here

**Solar PV Standard Plan — Simplified 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 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 the load side of

a single-phase AC service panel of nominal 120/240Vac with a bus bar rating of 225A or less. This plan is not intended for bipolar

systems, hybrid systems or systems that utilize storage batteries, charge controllers, trackers, more than two inverters or more than one

DC combiner (noninverter-integrated) per inverter. 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 inverter, 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” and the “Load Center Calculations” 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 (Check box next to which lowest expected temperature is used):

1) Lowest expected ambient temperature for the location (TL ) = **Between -1° to -5° C**

Lowest expected ambient temperature for the location (TL ) = **Between -6° to -10° C**

Average ambient high temperature (TH) = 47° C

Note: For a lower TL or a higher TH, use the Comprehensive Standard Plan

DC Information:

|  |  |
| --- | --- |
| Module Manufacturer: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Model: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ | |
| 2) Module Voc (from module nameplate): \_\_\_\_Volts | 3) Module Isc (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: | |
| 6) Are DC/DC Converters used? Yes No If No, skip to Step 7. If Yes enter info below. | | |
| DC/DC Converter Model #:  Max DC Output Current: Amps  Max # of DC/DC Converters in an Input Circuit: | | DC/DC Converter Max DC Input Voltage: Volts Max DC Output Current: Volts DC/DC Converter Max DC Input Power: Watts |
| 7) Maximum System DC Voltage — Use A1 or A2 for systems without DC/DC converters, and B1 or B2 with DC/DC Converters.  A1. Module VOC (STEP 2) = x # in series (STEP 5) x 1.12 (If -1 ≤ TL ≤ -5°C, STEP 1) = V  A2. Module VOC (STEP 2) = x # in series (STEP 5) x 1.14 (If -6 ≤ TL ≤ -10°C, STEP 1) = V  Use for DC/DC converters. The value calculated below must be less than DC/DC converter max DC input voltage (STEP 6).  B1. Module VOC (STEP 2) = x # of modules per converter (STEP 6) x 1.12 (If -1 ≤ TL ≤ -5°C, STEP 1) = V  B2. Module VOC (STEP 2) = x # of modules per converter (STEP 6) x 1.14 (If -6 ≤ TL ≤ -10°C, STEP 1) = V | | |
| 8) Maximum System DC Voltage from DC/DC Converters to Inverter — Only required if Yes in Step 6  Maximum System DC Voltage = Volts | | |
| 9) Maximum Source Circuit Current  Is Module ISC below 9.6 Amps (Step 3)? Yes No (If No, use Comprehensive Standard Plan) | | |

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| Table 1. Maximum Number of PV Modules in Series Based on Module Rated VOC for 600 Vdc Rated Equipment (CEC 690.7) | | | | | | | | | | | | | |
| Max. Rated Module VOC (\*1.12) (Volts) | 29.76 | 31.51 | 33.48 | 35.71 | 38.27 | 41.21 | 44.64 | 48.70 | 53.57 | 59.52 | 66.96 | 76.53 | 89.29 |
| Max. Rated Module VOC (\*1.14) (Volts) | 29.24 | 30.96 | 32.89 | 35.09 | 37.59 | 40.49 | 43.86 | 47.85 | 52.63 | 58.48 | 65.79 | 75.19 | 87.72 |
| Max # of Modules for 600 Vdc | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 |

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| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Table 2. Largest Module VOC for Single-Module DC/DC Converter Configurations (with 80 V AFCI Cap) (CEC 690.7 and 690.11) | | | | | | | | | | | | | | | | |
| Max. Rated Module VOC (\*1.12) (Volts) | 30.4 | 33.0 | 35.7 | 38.4 | 41.1 | 43.8 | 46.4 | 49.1 | 51.8 | 54.5 | 57.1 | 59.8 | 62.5 | 65.2 | 67.9 | 70.5 |
| Max. Rated Module VOC (\*1.14) (Volts) | 29.8 | 32.5 | 35.1 | 37.7 | 40.4 | 43.0 | 45.6 | 48.2 | 50.9 | 53.5 | 56.1 | 58.8 | 61.4 | 64.0 | 66.7 | 69.3 |
| DC/DC Converter Max DC Input  (Step #6) (Volts) | 34 | 37 | 40 | 43 | 46 | 49 | 52 | 55 | 58 | 61 | 64 | 67 | 70 | 73 | 76 | 79 |

|  |
| --- |
| 10) Sizing Source Circuit Conductors  Source Circuit Conductor Size = Min. #10 AWG copper conductor, 90° C wet (USE-2, PV Wire, XHHW-2,  THWN-2, RHW-2)  For up to 8 conductors in roof-mounted conduit exposed to sunlight at least ½” from the roof covering (CEC 310)  Note: For over 8 conductors in the conduit or mounting height of lower than ½” from the roof, use Comprehensive Plan. |
| 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 with Single Line Diagram 4 and proceed to Step 12.  Is source circuit OCPD required? Yes No  Source circuit OCPD size (if needed): 15 Amps |
| 12) Sizing PV Output Circuit Conductors — If a combiner box will NOT be used (Step 11), Output Circuit Conductor Size = Min. #6 AWG copper conductor |
| 13) Inverter DC 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) |
| 14) Inverter Information  Manufacturer: Model:  Max. Continuous AC Output Current Rating: Amps  Integrated DC Arc-Fault Circuit Protection? Yes No (If No is selected, Comprehensive Standard Plan)  Grounded or Ungrounded System? Grounded Ungrounded |

AC Information:

15) Sizing Inverter Output Circuit Conductors and OCPD Inverter Output OCPD rating = Amps (Table 3)

Inverter Output Circuit Conductor Size = AWG (Table 3)

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Table 3. Minimum Inverter Output OCPD and Circuit Conductor Size | | | | | | | | | |
| Inverter Continuous Output Current Rating (Amps) (Step 14) | 12 | 16 | 20 | 24 | 28 | 32 | 36 | 40 | 48 |
| Minimum OCPD Size (Amps) | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 60 |
| Minimum Conductor Size (AWG, 75° C, Copper) | 14 | 12 | 10 | 10 | 8 | 8 | 6 | 6 | 6 |

16) Point of Connection to Utility

Only load side connections are permitted with this plan. Otherwise, use Comprehensive Standard Plan.

Is the PV OCPD positioned at the opposite end from input feeder location or main OCPD location? Yes No If Yes, circle the Max Combined PV System OCPD(s) at 120% value as determined from Step 15 (or Step S20), bus bar Rating, and Main OCPD as shown in Table 4.

If No, circle the Max Combined PV System OCPD(s) at 100% value as determined from Step 15 (or Step

S20), bus bar Rating, and Main OCPD as shown in Table 4.

Per 705.12(D)(2): [Inverter output OCPD size [Step #15 or S20] + Main OCPD Size] ≤ [bus size x (100%

or 120%)]

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Table 4. Maximum Combined Supply OCPDs Based on Bus Bar Rating (Amps) per CEC 705.12(D)(2) | | | | | | | | | |
| Bus Bar Rating | 100 | 125 | 125 | 200 | 200 | 200 | 225 | 225 | 225 |
| Main OCPD | 100 | 100 | 125 | 150 | 175 | 200 | 175 | 200 | 225 |
| Max Combined PV System OCPD(s)  at 120% of Bus Bar Rating | 20 | 50 | 25 | 60\* | 60\* | 40 | 60\* | 60\* | 45 |
| Max Combined PV System OCPD(s)  at 100% Bus Bar Rating | 0 | 25 | 0 | 50 | 25 | 0 | 50 | 25 | 0 |

\*This value has been lowered to 60 A from the calculated value to reflect 10 kW AC size maximum.

Reduction of the main breaker is not permitted with this plan. Otherwise, use Comprehensive

Standard Plan.

17 & 18 & 19) Labels and Grounding and Bonding

This content is covered by the labels on the next page and the Single Line Diagram(s). For background

information, refer to the Comprehensive Standard Plan.

**Solar PV Standard Plan – Simplified**

**Central/String Inverter Systems for One- and Two-Family Dwellings**

**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**

**WARNING**

**DUAL POWER SOURCES**

**SECOND SOURCE IS PHOTOVOLTAIC SYSTEM**

**RATED AC OUTPUT CURRENT- \_\_\_\_AMPS AC NORMAL OPERATING VOLTAGE \_\_\_VOLTS**

**DC**

**INVERTER**

**AC**

**M**

**CEC 690.54 & CEC 705.12(D)(4)**

**CEC 705.12(D)(7)**

**[Not required if panelboard is rated not less than sum of ampere ratings of all overcurrent devices supplying it]**

**PV SYSTEM AC DISCONNECT**

**RATED AC OUTPUT CURRENT - \_\_\_\_AMPS**

**AC NORMAL OPERATING VOLTAGE \_\_\_VOLTS**

**WARNING**

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

**CEC 690.54**

**WARNING**

**ELECTRIC SHOCK HAZARD**

**IF A GROUND FAULT IS INDICATED,**

**NORMALLY GROUNDED CONDUCTORS MAY BE UNGROUNDED AND ENERGIZED**

**CEC 690.35(F)**

**[Only required for ungrounded systems]**

**CEC 690.5(C)**

**[Normally already present on listed inverters]**

**WARNING: PHOTOVOLTAIC POWER SOURCE**

**CEC 690.53**

**PV SYSTEM DC DISCONNECT**

**RATED MAX POWER-POINT CURRENT- \_\_\_ADC**

**RATED MAX POWER-POINT VOLTAGE- \_\_\_VDC**

**SHORT CIRCUIT CURRENT- \_\_\_ADC**

**MAXIMUM SYSTEM VOLTAGE- \_\_\_VDC**

**WARNING**

**ELECTRIC SHOCK HAZARD**

**DO NOT TOUCH TERMINALS**

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

**CRC R331.2 and CFC 605.11.1**

**[Marked on junction/combiner boxes and conduit every 10’]**

**CEC 690.17**

**J/Box**

**Code Abbreviations:**

**California Electrical Code (CEC)**

**California Residential Code (CRC)**

**California Fire Code (CFC)**

**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.**

**Solar PV Standard Plan – Simplified**

**Central/String Inverter System for One- and Two-Family Dwellings**

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**Solar PV Standard Plan – Simplified**

**Central/String Inverter System for One- and Two-Family Dwellings**

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**Supplemental Calculation Sheets for Inverter #2 (Only include if second inverter is used)**

DC Information:

|  |  |  |
| --- | --- | --- |
| Module Manufacturer: Model: | | |
| S2) Module Voc (from module nameplate): Volts | | S3) Module Isc (from module nameplate): Amps |
| S4) Module DC output power under standard test conditions (STC) = Watts (STC) | | |
| S5) 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: | |
| S6) Are DC/DC Converters used? Yes No If No, skip to Step S7. If Yes, enter info below. | | |
| DC/DC Converter Model #:  Max DC Output Current: Amps  Max # of DC/DC Converters in an Input Circuit: | | DC/DC Converter Max DC Input Voltage: Volts Max DC Output Current: Volts DC/DC Converter Max DC Input Power: Watts |

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| S7) Maximum System DC Voltage — Use A1 or A2 for systems without DC/DC converters, and B1 or B2 with DC/DC Converters.  A1. Module VOC (STEP S2) = x # in series (STEP S5) x 1.12 (If -1 ≤ TL ≤ -5°C, STEP S1) = V  A2. Module VOC (STEP S2) = x # in series (STEP S5) x 1.14 (If -6 ≤ TL ≤ -10°C, STEP S1) = V  Use for DC/DC converters. The value calculated below must be less than DC/DC converter max DC input voltage (STEP S6).  B1. Module VOC (STEP S2) = x # of modules per converter (STEP S6) x 1.12 (If -1 ≤ TL ≤ -5°C, STEP S1) = V  B2. Module VOC (STEP S2) = x # of modules per converter (STEP S6) x 1.14 (If -6 ≤ TL ≤ -10°C, STEP S1) = V |
| S8) Maximum System DC Voltage from DC/DC Converters to Inverter — Only required if Yes in Step S6  Maximum System DC Voltage = Volts |
| S9) Maximum Source Circuit Current  Is Module ISC below 9.6 Amps (Step S3)? Yes No (If No, use Comprehensive Standard Plan) |
| S10) Sizing Source Circuit Conductors  Source Circuit Conductor Size = Min. #10 AWG copper conductor, 90° C wet (USE-2, PV Wire, XHHW-2,  THWN-2, RHW-2)  For up to 8 conductors in roof-mounted conduit exposed to sunlight at least ½” from the roof covering (CEC 310)  Note: For over 8 conductors in the conduit or mounting height of lower than ½” from the roof, use Comprehensive  Plan. |
| S11) Are PV source circuits combined prior to the inverter? Yes No  If No, use Single Line Diagram 1 and proceed to Step S13.  If Yes, use Single Line Diagram 2 with Single Line Diagram 4 and proceed to Step S12.  Is source circuit OCPD required? Yes No  Source circuit OCPD size (if needed): 15 Amps |
| S12) Sizing PV Output Circuit Conductors — If a combiner box will NOT be used (Step S11), Output Circuit Conductor Size = Min. #6 AWG copper conductor |
| S13) Inverter DC 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) |

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| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Table 1. Maximum Number of PV Modules in Series Based on Module Rated VOC for 600 Vdc Rated Equipment (CEC 690.7) | | | | | | | | | | | | | |
| Max. Rated Module VOC (\*1.12) (Volts) | 29.76 | 31.51 | 33.48 | 35.71 | 38.27 | 41.21 | 44.64 | 48.70 | 53.57 | 59.52 | 66.96 | 76.53 | 89.29 |
| Max. Rated Module VOC (\*1.14) (Volts) | 29.24 | 30.96 | 32.89 | 35.09 | 37.59 | 40.49 | 43.86 | 47.85 | 52.63 | 58.48 | 65.79 | 75.19 | 87.72 |
| Max # of Modules for 600 Vdc | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Table 2. Largest Module VOC for Single-Module DC/DC Converter Configurations (with 80 V AFCI Cap) (CEC 690.7 and 690.11) | | | | | | | | | | | | | | | | |
| Max. Rated Module VOC (\*1.12) (Volts) | 30.4 | 33.0 | 35.7 | 38.4 | 41.1 | 43.8 | 46.4 | 49.1 | 51.8 | 54.5 | 57.1 | 59.8 | 62.5 | 65.2 | 67.9 | 70.5 |
| Max. Rated Module VOC (\*1.14) (Volts) | 29.8 | 32.5 | 35.1 | 37.7 | 40.4 | 43.0 | 45.6 | 48.2 | 50.9 | 53.5 | 56.1 | 58.8 | 61.4 | 64.0 | 66.7 | 69.3 |
| DC/DC Converter Max DC Input  (Step 6) (Volts) | 34 | 37 | 40 | 43 | 46 | 49 | 52 | 55 | 58 | 61 | 64 | 67 | 70 | 73 | 76 | 79 |

S14) Inverter Information

Manufacturer:

Max. Continuous AC Output Current Rating: Amps

Model:

Integrated DC Arc-Fault Circuit Protection? Yes No (If No is selected, Comprehensive Standard Plan) Grounded or Ungrounded System? Grounded Ungrounded

AC Information:

S15) Sizing Inverter Output Circuit Conductors and OCPD Inverter Output OCPD rating = Amps (Table 3)

Inverter Output Circuit Conductor Size = AWG (Table 3)

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Table 3. Minimum Inverter Output OCPD and Circuit Conductor Size | | | | | | | | | |
| Inverter Continuous Output Current Rating (Amps) (Step 14) | 12 | 16 | 20 | 24 | 28 | 32 | 36 | 40 | 48 |
| Minimum OCPD Size (Amps) | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 60 |
| Minimum Conductor Size (AWG, 75° C, Copper) | 14 | 12 | 10 | 10 | 8 | 8 | 6 | 6 | 6 |

**Load Center Calculations**

**(Omit if a load center will not be installed for PV OCPDs)**

S20) Load Center Output:

Calculate the sum of the maximum AC outputs from each inverter.

Inverter #1 Max Continuous AC Output Current Rating [STEP S14] × 1.25 = Amps

Inverter #2 Max Continuous AC Output Current Rating [STEP S14] × 1.25 = Amps

Total inverter currents connected to load center (sum of above) = Amps

Conductor Size: AWG

Overcurrent Protection Device: Amps

Load center bus bar rating: Amps

The sum of the ampere ratings of overcurrent devices in circuits supplying power to a bus bar or conductor

shall not exceed 120 percent of the rating of the bus bar or conductor.

**Solar PV Standard Plan – Simplified**

**Central/String Inverter System for One- and Two-Family Dwellings**

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**Solar PV Standard Plan – Simplified**

**Central/String Inverter System for One- and Two-Family Dwellings**

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**Items required: roof layout of all panels, modules, clear access pathways and approximate locations of electrical disconnecting means and roof access points.**

**SOLAR PV STANDARD PLAN**

**Roof Layout Diagram for One- and Two-Family Dwellings**