



City of Imperial Beach, California

COMMUNITY DEVELOPMENT DEPARTMENT - BUILDING DIVISION

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PV Standard Plan - Simplified Central / String Inverter Systems for One & Two-Family Dwellings

SCOPE: Use this plan ONLY for electrical review of utility 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 a accessory building. The specific structural and fire requirements are covered in other parts of the California Solar Permitting Guidebook. This covers photovoltaic system interconnected to the load side of a single-phase AC service panel of nominal 120/240Vac with a bus bar rating of 225A or less. Plan also applies to supply side connections (between the meter and the service disconnects), where permitted by the local utility. This plan is not intended for bipolar systems, hybrid systems or systems that utilize storage batteries, charge controllers, trackers, more than two inverters, or strings combined. 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. For systems beyond this scope or the criteria in this plan, consult the AHJ for details regarding comprehensive process.

MANUFACTURER'S SPECIFICATION SHEETS MUST BE PROVIDED for proposed inverters, modules, combiner/junction boxes, racking systems, and rapid shutdown system or equipment. Installation instructions for bonding and grounding equipment and rapid shutdown systems 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 listed for the PV application (CEC 690.4[B]).

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

Ambient Temperature Adjustment Factors: select the box for the expected lowest ambient temperature (T_L) with the corresponding Ambient Temperature Correction Factor (C_F):

- 1) If T_L is greater than or equal to -5°C , $C_F = 1.12$
 If T_L is between -6°C and -10°C , $C_F = 1.14$
 Average ambient high temperature (T_H) $\leq 47^\circ\text{C}$
 Note: For a lower T_L or a higher T_H , this plan is not applicable.

DC Information:

Module Manufacturer: _____	Model: _____
2) Module V_{OC} (from module nameplate): _____ Volts	
3) Module I_{SC} (from module nameplate): _____ Amps	
Is Module I_{SC} less than 13 Amps? <input type="checkbox"/> Yes <input type="checkbox"/> No (If No, this plan is not applicable.)	
4) Module DC output power under standard test conditions (STC) = _____ Watts (STC)	

10) Inverter DC Disconnect

Does the inverter have an integrated DC disconnect? Yes No If Yes, skip to Step 11.
 If No, the external DC disconnect to be installed is rated for ___ Amps (DC) and ___ Volts (DC)

11) Inverter Information

Manufacturer: _____ Model: _____
 Max. Continuous AC Output Current Rating: _____ Amps
 Max. Short Circuit Current Per Input: _____ Amps
 Does PV Module I_{sc} (Step 3) exceed value above? Yes No (If No, this plan is not applicable.)
 Integrated DC Arc-Fault Circuit Protection? Yes No (If No is selected, this plan is not applicable.)
 Grounded or Underground System? Grounded Ungrounded

AC Information:

12) 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 11)	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	

13) Point of Connection to Utility – Inverter(s) must be connected to either load or supply side of service disconnecting means. Only one of the sub-sections below and either Single Line Diagram #1 or Single Line Diagram #2 should be filled out.

Only use this section for connections on the load side of the service disconnecting means.

Is the PV OCPD positioned at the opposite end from input feeder location or main OCPD location?

Yes No (If No, then use 100% row in Table 4)

Load side connections (Per 705.12(D)(2)(3)(c)):

(Combined inverter output OCPD size + Main OCPD size) ≤ [bus bar size × (100% or 120%)]

Table 4. Maximum Combined Supply OCPDs Based on Bus Bar Rating (Amps) per CEC 705.12(D)(2)(3)(b)										
Bus Bar Rating (Amps)	100	125	125	200	200	200	225	225	225	
Main OCPD (Amps)	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. Interconnection to center-fed panelboards may be permitted per Informational Bulletin.¹

Only use this section for connections on the supply side of the service disconnecting means (between the utility meter and the service disconnecting means). Select one:

Utility- and AHJ-approved meter socket adapter.

Adapter name/model: _____

Service equipment listed for the purpose of PV interconnection.

Description / model number(s): _____

¹ See Page 8, Part 1 of California Solar Permitting Guidebook for guidance. See CA BSC’s Information Bulletin 16-03.

14) Rapid Shutdown²

The rapid shutdown initiation device shall be labeled according to CEC 690.56(C), and its location shall be shown on the site plan drawing. The rapid shutdown initiation device may be the inverter output or input circuits' disconnecting means, the service main disconnect, or a separate device as approved by the AHJ. The disconnecting means shall be identified for the purpose, suitable for their environment, and listed as a disconnecting means. A single rapid shutdown initiation device shall operate all disconnecting means necessary to control conductors in compliance with CEC 690.12. Note: Check with the AHJ regarding approval where field verification of reduction of voltage within the time required by CEC 690.12 is performed.

Rapid shutdown shall be provided as required by CEC 690.12 with one of the following methods (Select one):

- The inverter(s) is within 10 feet of the array, and the location of the inverter is such that uncontrolled PV system conductors are no greater than 5 feet of length within the building. A remotely-controlled AC disconnecting means is required immediately adjacent to or as close as practicable to the inverters, and located within 10 feet of the array.
- The inverter(s) is within 10 feet of the array, and the location of the inverter is such that uncontrolled PV system conductors are no greater than 5 feet of length within the building. Reduction of the voltage for the inverter output within the time required by CEC 690.12 shall be verified in the field, or the inverter output is listed to UL 1741 with rapid shutdown capability.
- Remotely-controlled DC disconnecting means are located within 10 feet of the PV array and DC input of the inverter(s), and the locations of the disconnecting means are such that uncontrolled PV system conductors are no greater than 5 feet of length within the building. Reduction of the voltage for the inverter output within the time required by CEC 690.12 shall be verified in the field, or the inverter output is listed to UL 1741 with rapid shutdown capability.
- Remotely-controlled DC disconnecting means is located within 10 feet of the array at the DC input of inverter(s) connected to a module level DC-DC converter circuit where the DC-DC converter circuit meets the requirements for controlled conductors when disconnected from the inverter. Reduction of the voltage for the DC-DC converter output and the inverter output within the time required by CEC 690.12 shall be verified in the field, or the DC-DC converter output and the inverter output are listed to UL 1741 with rapid shutdown capability.
- A UL 1741-listed and identified inverter(s) with input and output rapid shutdown capability supplying module level DC-DC converter circuit where the DC-DC converter circuit meets the requirements for controlled conductors when disconnected from the inverter.
- A UL 1741-listed rapid shutdown system:
Manufacturer: _____
Testing Agency Name: _____
System Model Number: _____
System Components: _____

15) Grounding and Bonding of Modules and Racking System (select one):

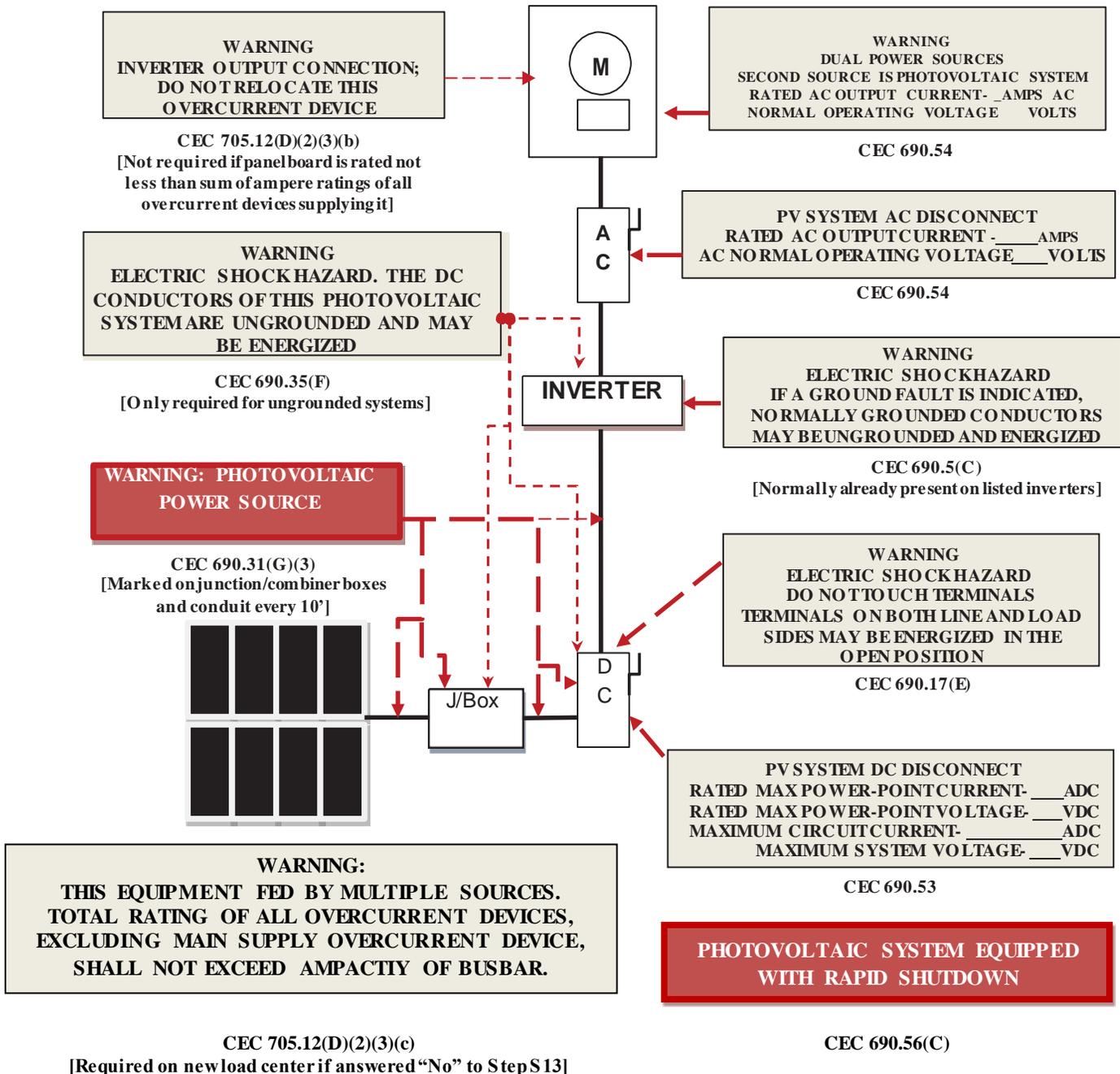
- Racking system listed to UL 2703 using modules identified in the listing.
- Other method subject to AHJ approval

² See Page 8, Part 1 of the California Solar Permitting Guidebook for guidance. See CA BSC's Information Bulletin 16-03.

Solar PV Standard Plan — Simplified Central/String Inverter Systems for One- and Two-Family Dwellings

Markings

CEC Articles 690 and 705 and CA Residential Code Section R324 require the following labels or markings be installed at these components of the photovoltaic system:



Informational note: ANSI Z535.4-2011 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 or rapid fire shutdown equipment.

Solar PV Standard Plan — Simplified Central/String Inverter Systems for One- and Two-Family Dwellings

TAG	DESCRIPTION	
1	SOLAR PV MODULE / STRING	<h3 style="margin: 0;">SINGLE-LINE DIAGRAM #1 – LOAD SIDE CONNECTION</h3> <p style="margin: 5px 0;">CHECK A BOX FOR WHETHER SYSTEM IS GROUNDED OR UNGROUNDED: <input type="checkbox"/> GROUNDED (INCLUDE GEC) <input type="checkbox"/> UNGROUNDED</p> <p style="margin: 5px 0;">REFER TO STEP 14 FOR RAPID SHUTDOWN DETAILS</p> <p style="margin: 5px 0;">FOR UNGROUNDED SYSTEMS:</p> <ul style="list-style-type: none"> - 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.
2	DC/DC CONVERTERS INSTALLED? YES / NO (IF YES, STEPS 6 & 8 REQUIRED)	
3	SOURCE CIRCUIT JUNCTION BOX INSTALLED? YES / NO	
4	SEPARATE DC DISCONNECT INSTALLED? YES / NO	
5	INTERNAL INVERTER DC DISCONNECT: YES / NO	
6	CENTRAL INVERTER	
7	LOAD CENTER INSTALLED? YES / NO	
8	PV PRODUCTION METER INSTALLED? YES / NO	
9	*SEPARATE AC DISCONNECT INSTALLED? YES / NO	
10	CONNECT TO INVERTER #2 (USE LINE DIAGRAM 3)	

* Consult with your local AHJ and /or Utility

Inverter Make: _____
Inverter Model: _____

MAIN SERVICE PANEL
BUSBAR RATING: _____
MAIN OCPD RATING: _____
PV OCPD RATING: _____

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

CONDUCTOR/CONDUIT SCHEDULE					
TAG	DESCRIPTION AND CONDUCTOR TYPE	CONDUCTOR SIZE	NUMBER OF CONDUCTORS	CONDUIT/CABLE TYPE	CONDUIT SIZE
A	USE-2 <input type="checkbox"/> OR PV-WIRE <input type="checkbox"/>				
	EGC/GEC:				
B					
	EGC/GEC:				
C					
	EGC/GEC:				
D					
	EGC/GEC:				

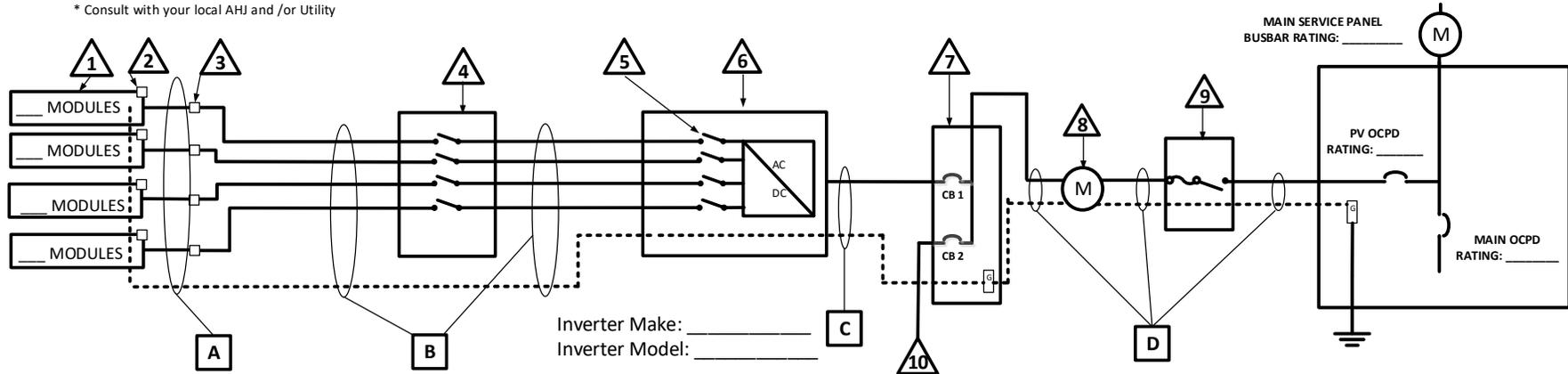
Solar PV Standard Plan — Simplified Central/String Inverter Systems for One- and Two-Family Dwellings

△ TAG	DESCRIPTION
1	SOLAR PV MODULE / STRING
2	DC/DC CONVERTERS INSTALLED? YES / NO (IF YES, STEPS 6 & 8 REQUIRED)
3	SOURCE CIRCUIT JUNCTION BOX INSTALLED?: YES / NO
4	SEPARATE DC DISCONNECT INSTALLED?: YES / NO
5	INTERNAL INVERTER DC DISCONNECT: YES / NO
6	CENTRAL INVERTER
7	LOAD CENTER INSTALLED?: YES / NO
8	PV PRODUCTION METER INSTALLED?: YES / NO
9	*SEPARATE AC DISCONNECT INSTALLED?: YES / NO
10	CONNECT TO INVERTER #2 (USE LINE DIAGRAM 3)

SINGLE-LINE DIAGRAM #2 – SUPPLY SIDE CONNECTION

CHECK A BOX FOR WHETHER SYSTEM IS GROUNDED OR UNGROUNDED: GROUNDED (INCLUDE GEC) UNGROUNDED
 REFER TO STEP 14 FOR RAPID SHUTDOWN DETAILS
 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



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

CONDUCTOR/CONDUIT SCHEDULE

<input type="checkbox"/> TAG	DESCRIPTION AND CONDUCTOR TYPE	CONDUCTOR SIZE	NUMBER OF CONDUCTORS	CONDUIT/CABLE TYPE	CONDUIT SIZE
A	USE-2 <input type="checkbox"/> OR PV-WIRE <input type="checkbox"/>				
	EGC/GEC:				
B					
	EGC/GEC:				
C					
	EGC/GEC:				
D					
	EGC/GEC:				

Select one interconnection method:
 Utility- and AHJ-approved meter socket adapter.
 Adapter name/model: _____
 Service equipment listed for purpose of PV interconnection.
 Description / model number: _____

**Solar PV Standard Plan — Simplified
Central/String Inverter Systems for One- and Two-Family Dwellings
Supplemental Calculation Sheets for Inverter #2 (Only
include if second inverter is used)**

DC Information:

Module Manufacturer: _____ Model: _____	
S2) Module V_{oc} (from module nameplate): _____ Volts	
S3) Module I_{sc} (from module nameplate): _____ Amps Is Module I_{sc} less than 13 Amps? <input type="checkbox"/> Yes <input type="checkbox"/> No (If No, this plan is not applicable.)	
S4) Module DC output power under standard test conditions (STC) = _____ Watts (STC)	
S5) DC Module Layout	
Identify each source circuit (string) for inverter 2 shown on the roof plan with a Tag (e.g. A,B,C,...)	Number of modules per source circuit for inverter 2

Total number of source circuits for inverter

S7) Maximum System DC Voltage

Only use for systems without DC/DC converters.

A. Module V_{OC} (Step S2) _____ x # of modules in series (Step S5) _____ x C_F (Step 1) _____ = _____ V

Table S1. Maximum Number of PV Modules in Series Based on Module Rated V_{OC} for 600 Vdc Rated Equipment (CEC 690.7)													
Max. Rated Module V_{OC} if $C_F = 1.12$ (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 V_{OC} if $C_F = 1.14$ (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

Only use for systems with DC/DC converters. The value calculated below must be less than DC/DC converter max DC input voltage (Step S6).

B. Module V_{OC} (Step S2) _____ x # of modules per converter (Step S6) _____ x C_F (Step 1) _____ = _____ V

Table S2. Largest Module V_{OC} for Single-Module DC/DC Converter Configurations (with 80 V AFCI Cap) (CEC 690.7 and 690.11)																
Max. Rated Module V_{OC} if $C_F = 1.12$ (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 V_{OC} if $C_F = 1.14$ (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

S8) Maximum System DC Voltage from DC/DC Converters to Inverter — Only required if Yes in Step S6

Maximum System DC Voltage = _____ Volts

S9) 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 current-carrying conductors in roof-mounted conduit exposed to sunlight at least ½” from the roof covering. (CEC 310)

Note: For over 8 current-carrying conductors in the conduit or mounting height of lower than ½” from the roof, this plan is not applicable.

S10) Inverter Disconnect

Does the inverter have an integrated DC disconnect? Yes No If Yes, skip to Step S11.

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

S11) Inverter Information

Manufacturer: _____ Model: _____

Max. Continuous AC Output Current Rating: _____ Amps

Max. Short Circuit Current Per Input: _____ Amps

Does PV Module I_{sc} (Step S3) exceed value above? Yes No (If No, this plan is not applicable.)

Integrated DC Arc-Fault Circuit Protection? Yes No (If No is selected, this plan is not applicable.)

Grounded or Underground System? Grounded Ungrounded

AC Information:

S12) Inverter Information

Inverter Output OCPD rating = _____ Amps (Table S3)

Inverter Output Circuit Conductor Size = _____ AWG (Table S3)

Table S3. Minimum Inverter Output OCPD and Circuit Conductor Size									
Inverter Continuous Output Current Rating (Amps) (Step S13)	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)

S11) Load Center Output:

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

Inverter #1 Max Continuous AC Output Current Rating [STEP 11] _____ × 1.25 = _____ Amps

Inverter #2 Max Continuous AC Output Current Rating [STEP S11] _____ × 1.25 = _____ Amps

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

Conductor Size: _____ AWG

Overcurrent Protection Device: _____ Amps

Load center busbar rating: _____ Amps

Can the load center accept more than two breakers? Yes No

If Yes, the sum of 125% of the inverter output circuit currents and the rating of the overcurrent device protecting the busbar shall not exceed 120% of the ampacity of the busbar.

If No, the sum of ampere rating of the two PV overcurrent devices shall not exceed the rating of the busbar.

Solar PV Standard Plan — Simplified Central/String Inverter Systems for One- and Two-Family Dwellings

△ TAG	DESCRIPTION	SINGLE-LINE DIAGRAM #3 – ADDITIONAL INVERTER			
1	SOLAR PV MODULE / STRING	<p>INVERTER # 2</p> <p>CHECK A BOX FOR WHETHER SYSTEM IS GROUNDED OR UNGROUNDED: <input type="checkbox"/> GROUNDED (INCLUDE GEC) <input type="checkbox"/> UNGROUNDED</p> <p>REFER TO STEP 14 FOR RAPID SHUTDOWN DETAILS</p> <p>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.</p>			
2	DC/DC CONVERTERS INSTALLED? YES / NO (IF YES, STEPS 6 & 8 REQUIRED)				
3	SOURCE CIRCUIT JUNCTION BOX INSTALLED?: YES / NO				
4	SEPARATE DC DISCONNECT INSTALLED?: YES / NO				
5	INTERNAL INVERTER DC DISCONNECT: YES / NO				
6	CENTRAL INVERTER				
7	*SEPARATE AC DISCONNECT INSTALLED?: YES / NO				
8	TO LOAD CENTER ON LINE DIAGRAM 1				
* Consult with your local AHJ and /or Utility		<p style="text-align: center;">Inverter Make: _____ Inverter Model: _____</p>			
CONDUCTOR/CONDUIT SCHEDULE					
□ TAG	DESCRIPTION AND CONDUCTOR TYPE	CONDUCTOR SIZE	NUMBER OF CONDUCTORS	CONDUIT/CABLE TYPE	CONDUIT SIZE
A	USE-2 <input type="checkbox"/> OR PV-WIRE <input type="checkbox"/>				
	EGC/GEC:				
B					
	EGC/GEC:				
C					
	EGC/GEC:				

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

SOLAR PV STANDARD PLAN

Roof Layout Diagram for One- and Two-Family Dwellings



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