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 (β or Ɛ) 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} temperature coefficient (β)= _______ %/°C

Module Count per source circuit ___ × {V_{OC} + [(T_L-25) × (β × V_{OC})/100]} = _______ Volts

If module manufacturer provides a voltage temperature coefficient (Ɛ) in mV/°C, use the formula below.

V_{OC} temperature coefficient (Ɛ)= _______ mV/°C

Module Count per source circuit ___ × {V_{OC} + [(T_L-25) × (Ɛ/1000)]} = _______ Volts

Method 2:

Module Count per source circuit ___ × V_{OC} _______ × K_T = _______ Volts,

where K_T= ________ is a correction factor for ambient temperatures below 25°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 eIQ 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.

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_F 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)(3)(c) and 310.15(B)(2)(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 ~~3~~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 ~~8A~~ 11A or ~~8B~~ 11B 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

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 (~~=0 if not applicable~~N/A if inapplicable)

C_F = ____ C_T = ____

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

Using the greater current as calculated in **Method A** or **Method B**, use Table 310.15(B)(16) to identify 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~~=0 if not applicable~~)

C_F = ____ C_T = ____

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_F 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#14]_____ / (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

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 × (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	225
Main OCPD	100	100	125	150	175	200	175	200	225
Max Combined PV System OCPD(s) at 120% of Busbar Rating	20	50	25	60*	60*	40	60*	60*	45
Max Combined PV System OCPD(s) 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} _____ × { 1 (one source circuit) OR _____ (# source circuits in parallel [STEP#5] } **_________ Amps**

(b) Rated maximum power-point voltage (V_{mpp} from the module nameplate):

V_{mpp}_____ × __________ { Max # of modules per source circuit [STEP#5] } **_________ 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) ______ × ______ (Number of strings) **_________ Amps**

(d) Maximum system voltage [STEP#7 or #8 for systems with dc/dc converters] **_________ Volts**

[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 <u>OR</u> the 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:

AC Output Inverter 1 [STEP#14]	**__________ Amps**
AC Output Inverter 2 [If Applicable]	**__________ Amps**
Rated ac output current (sum of above values):	**__________ Amps**
(b) Nominal operating ac voltage:	**__________ Volts**

19) <u>Grounding and Bonding</u>:

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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.

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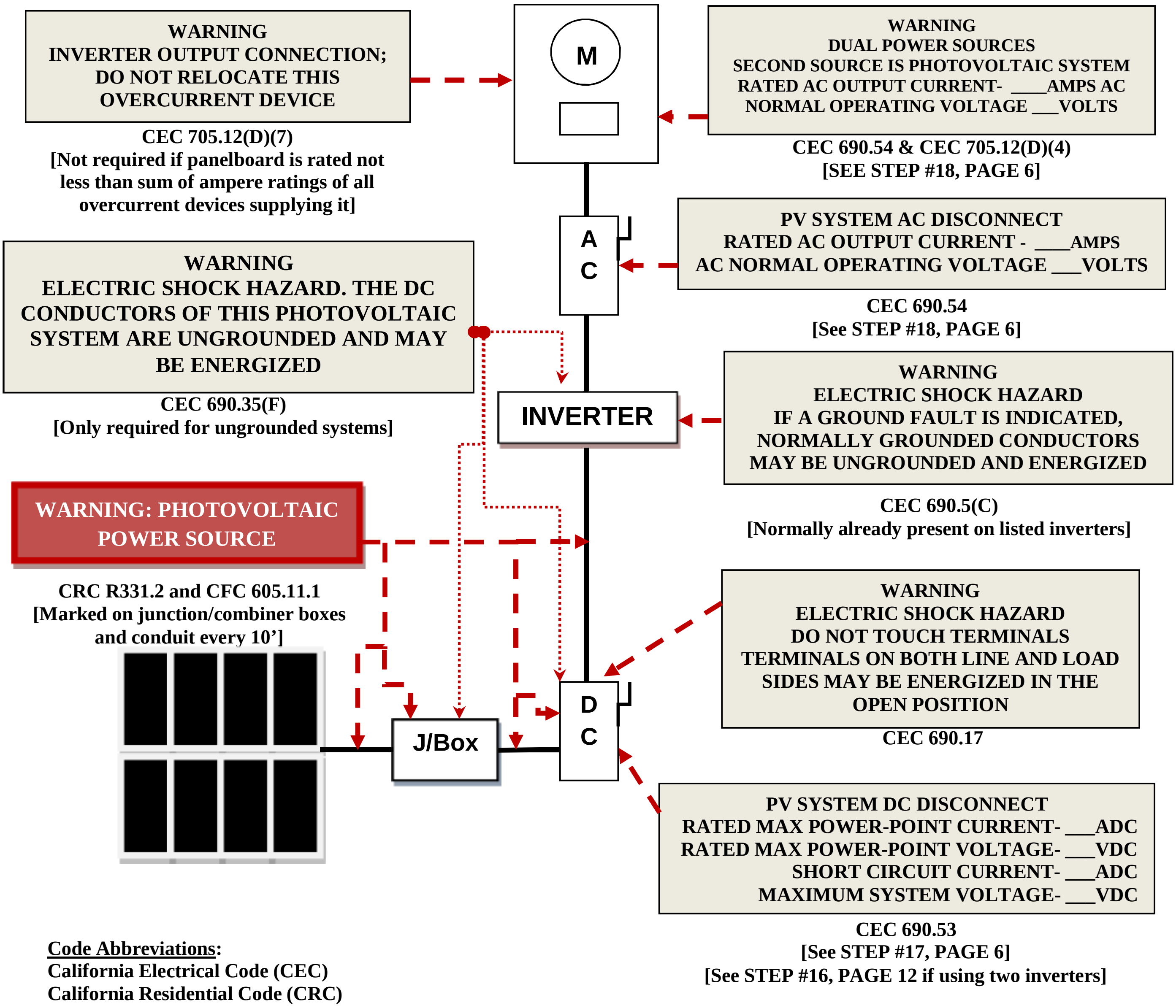
Central/String Inverter Systems for One and Two Family Dwellings

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:



<u>Code Abbreviations</u>:
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.

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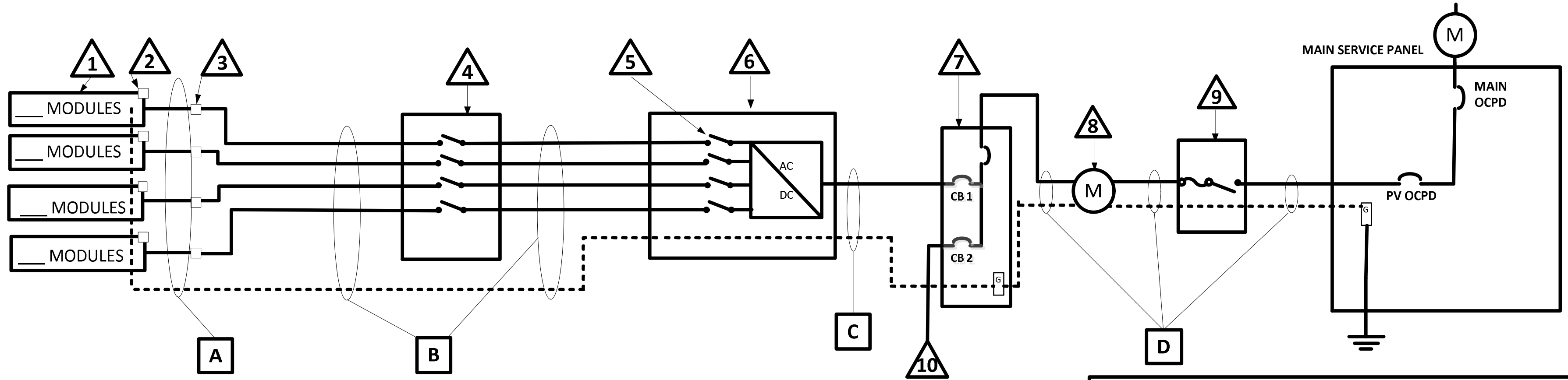
TAG	DESCRIPTION
1	SOLAR PV MODULE / STRING
2	DC/DC CONVERTERS INSTALLED? YES / NO (IF YES, STEPS 6 & 8 REQUIRED)
3	SOURCE CIRCUIT JUNCTION BOX INSTALLED?: YES / NO
4	SEPARATE DC DISCONNECT INSTALLED?: YES / NO
5	INTERNAL INVERTER DC DISCONNECT: YES / NO
6	CENTRAL INVERTER
7	LOAD CENTER INSTALLED?: YES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

* 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**

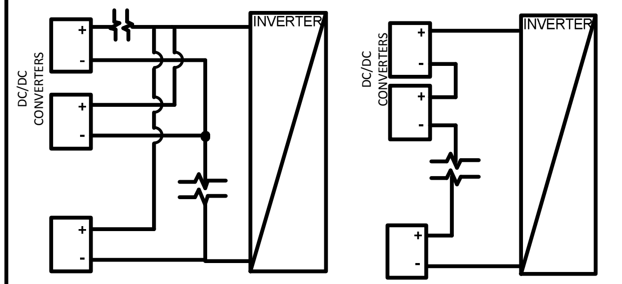
FOR UNGROUNDED SYSTEMS:
- **DC OCPD MUST DISCONNECT BOTH CONDUCTORS OF EACH SOURCE CIRCUIT**
- **UNGROUNDED CONDUCTORS MUST BE IDENTIFIED PER 210.5(C). WHITE-FINISHED CONDUCTORS ARE NOT PERMITTED.**



CONDUCTOR/CONDUIT SCHEDULE					
☐ TAG	DESCRIPTION AND CONDUCTOR TYPE	CONDUCTOR SIZE	NUMBER OF CONDUCTORS	CONDUIT/CABLE TYPE	CONDUIT SIZE
A	USE-2 ☐ OR PV-WIRE ☐				
	EGC/GEC:				
B					
	EGC/GEC:				
C					
	EGC/GEC:				
D					
	EGC/GEC:				

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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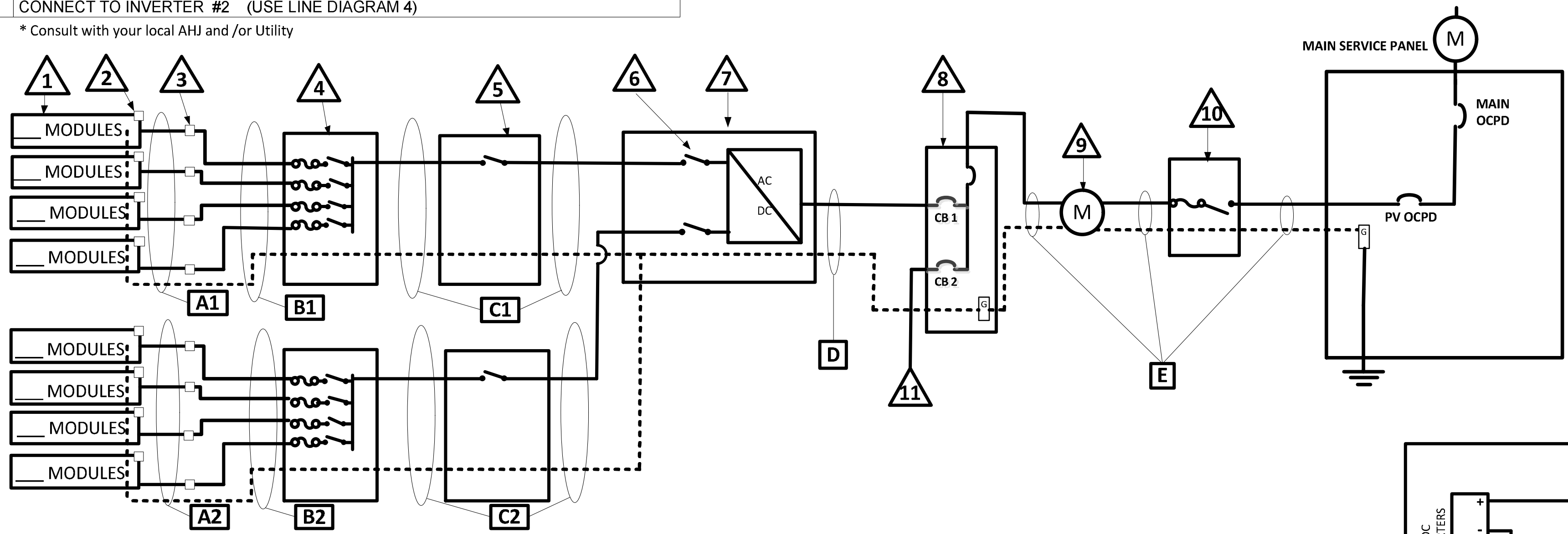
△TAG	DESCRIPTION
1	SOLAR PV MODULE / STRING
2	DC/DC CONVERTERS INSTALLED? YES / NO (IF YES, STEPS 6 & 8 REQUIRED)
3	SOURCE CIRCUIT JUNCTION BOX INSTALLED?: YES / NO
4	COMBINER BOX (STEPS 11 & 12 REQUIRED)
5	SEPARATE DC DISCONNECT INSTALLED?: YES / NO
6	INTERNAL INVERTER DC DISCONNECT: YES / NO
7	CENTRAL INVERTER
8	LOAD CENTER INSTALLED?: YES / NO
9	PV PRODUCTION METER INSTALLED?: YES / NO
10	*SEPARATE AC DISCONNECT INSTALLED?: YES / NO
11	CONNECT TO INVERTER #2 (USE LINE DIAGRAM 4)

* 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.

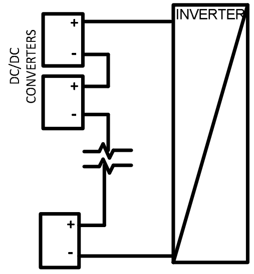


☐ TAG	DESCRIPTION AND CONDUCTOR TYPE	CONDUCTOR SIZE	NUMBER OF CONDUCTORS	CONDUIT/CABLE TYPE	CONDUIT SIZE
A1	USE-2 ☐ OR PV-WIRE ☐				
	EGC/GEC:				
B1					
	EGC/GEC:				
C1					
	EGC/GEC:				
D					
	EGC/GEC:				
E					
	EGC/GEC:				

CONDUCTOR/CONDUIT SCHEDULE

☐ TAG	DESCRIPTION AND CONDUCTOR TYPE	CONDUCTOR SIZE	NUMBER OF CONDUCTORS	CONDUIT/CABLE TYPE	CONDUIT SIZE
A2	USE-2 ☐ OR PV-WIRE ☐				
	EGC/GEC:				
B2					
	EGC/GEC:				
C2					
	EGC/GEC:				

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



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

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Supplemental Calculation Sheets for Inverter #2:

(Only include if no more than one additional inverter is used)

DC Information:

Module Manufacturer: ______________________	**Model:** ____________________
S2) Module V_{oc} (from module nameplate): ______Volts	**S3) Module I_{sc} (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 2 shown on the roof plan with a Tag (e.g. A,B,C,…)	**Number of modules per source circuit for inverter 2**	**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 2:		

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 (β or Ɛ) 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 (β)= _______ %/°C

Module Count per source circuit ___ × {V_{OC} + [(T_L-25) × (β × V_{OC})/100]} = _______ Volts

If module manufacturer provides a voltage temperature coefficient (Ɛ) in mV/°C, use the formula below.

V_{OC} temperature coefficient (Ɛ)= _______ mV/°C

Module Count per source circuit ___ × {V_{OC} + [(T_L-25) × (Ɛ/1000)]} = _______ Volts

Method 2:

Module Count per source circuit ___ × V_{OC} _______ × K_T = _______ Volts,

where K_T= _________ is a correction factor for ambient temperatures below 25°C. See Table 690.7.

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**.f

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 I_{SC} [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

C_F = ____ C_F 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)(3)(c) and 310.15(B)(2)(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#S9]_____ / (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 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

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(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 ~~1~~ 3 and proceed to **STEP#S13**.

If Yes, use Single Line Diagram ~~3~~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 ~~8~~S11A or ~~8~~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~~=0 if not applicable~~)

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~~=0 if not applicable~~)

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].

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_F 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]_____ / ($C_F \times C_T$) = ____ 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

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#9, if no strings are combined prior to inverter)

Maximum source circuit current (STEP#S9) _______ × _______ (Number of strings) __________ Amps

(d) Maximum system voltage [STEP#S7 or #S8 for systems with dc/dc converters] __________ Volts

[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 <u>OR</u> the value calculated in STEP#S8.]

Load Center Calculations:

(Only include if a load center will be installed)

S20) <u>Maximum output for each inverter</u>:

From supplemental calculation sheet used, list the calculated maximum ac output value [STEP#~~S15~~S14]:

Inverter #1 Maximum ac output: _____Amps

Inverter #2 Maximum ac output: _____Amps

S21) Load Center Output:

Calculate the sum of the maximum ac outputs from [STEP#S20].

Total inverter currents connected to load center = _____Amps

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

C_F = ____ C_F 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)(3)(c) and 310.15(B)(2)(a)

Minimum conductor ampacity: Maximum ac output current rating [STEP#S21]_____ / (C_F × C_T) = ____ 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.

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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	*SEPARATE AC DISCONNECT INSTALLED?: YES / NO
8	TO LOAD CENTER ON LINE DIAGRAM 1

* Consult with your local AHJ and /or Utility

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

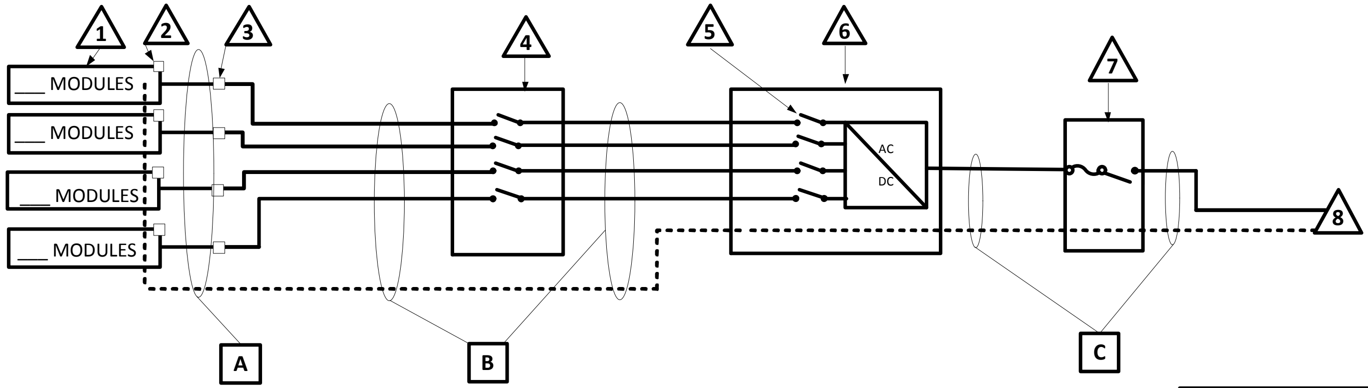
INVERTER # 2

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.

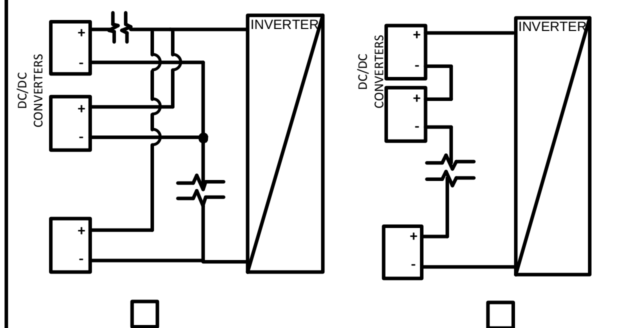


☐ TAG	DESCRIPTION AND CONDUCTOR TYPE	CONDUCTOR SIZE	NUMBER OF CONDUCTORS	CONDUIT/CABLE TYPE	CONDUIT SIZE
A	USE-2 ☐ OR PV-WIRE ☐				
	EGC/GEC:				
B					
	EGC/GEC:				
C					
	EGC/GEC:				

CONDUCTOR/CONDUIT SCHEDULE

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)

SOLAR PV STANDARD PLAN - COMPREHENSIVE

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	COMBINER BOX (STEPS 11 & 12 REQUIRED)
5	SEPARATE DC DISCONNECT INSTALLED?: YES / NO
6	INTERNAL INVERTER DC DISCONNECT: YES / NO
7	CENTRAL INVERTER
8	*SEPARATE AC DISCONNECT INSTALLED?: YES / NO
9	TO LOAD CENTER ON LINE DIAGRAM 3

* Consult with your local AHJ and /or Utility

SINGLE-LINE DIAGRAM #4 – ADDITIONAL INVERTER FOR DIAGRAM #2

INVERTER # 2

CHECK A BOX FOR WHETHER SYSTEM IS GROUNDED OR UNGROUNDED:

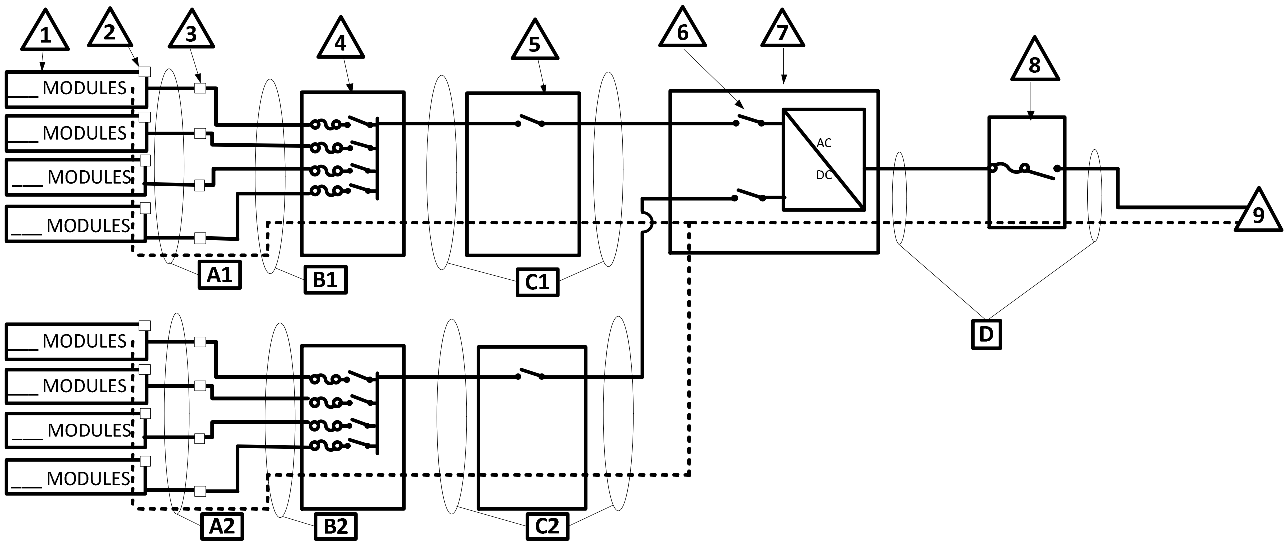
☐ **GROUNDED (INCLUDE GEC)**

☐ **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.



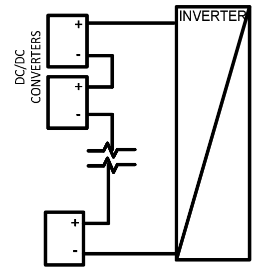
CONDUCTOR/CONDUIT SCHEDULE

☐ TAG	DESCRIPTION AND CONDUCTOR TYPE	CONDUCTOR SIZE	NUMBER OF CONDUCTORS	CONDUIT/CABLE TYPE	CONDUIT SIZE
A1	USE-2 ☐ OR PV-WIRE ☐				
	EGC/GEC:				
B1					
	EGC/GEC:				
C1					
	EGC/GEC:				
D					
	EGC/GEC:				

CONDUCTOR/CONDUIT SCHEDULE

☐ TAG	DESCRIPTION AND CONDUCTOR TYPE	CONDUCTOR SIZE	NUMBER OF CONDUCTORS	CONDUIT/CABLE TYPE	CONDUIT SIZE
A2	USE-2 ☐ OR PV-WIRE ☐				
	EGC/GEC:				
B2					
	EGC/GEC:				
C2					
	EGC/GEC:				

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



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