SOLAR PV MICROINVERTER/ACM STANDARD PLAN - COMPREHENSIVE

Microinverter and ACM Systems for One- and Two- Family Dwellings

***SCOPE:** Use this plan ONLY for systems using utility-interactive Microinverters or AC Modules (ACM) not exceeding a combined system AC inverter output rating of 10 kW with a maximum of 4 branch circuits, one PV modules per inverter, and installed on a roof of a one or two family dwelling or building. The specific structural and fire requirements are covered under a separate permit. The photovoltaic system must interconnect to a single-phase AC service panel of nominal 120/240 VAC with busbar rating of 225 A or less. This plan is not intended for bipolar systems, hybrid systems, or systems that utilize storage batteries, charge controllers, or tracker. 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 section 690.3.*

***MANUFACTURER'S SPECIFICATION SHEETS MUST BE PROVIDED**, as necessary, for proposed microinverters, modules, ACM, junction boxes and racking systems, and any additional equipment or systems for rapid shutdown. 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 listed for the application (CEC 690.4(B)).*

Applicant and Site Information

Job Address: ____ **Permit #:** __________________________________

Contractor/ Engineer Name: _________________________________ **License # and Class:** _________________________

Signature: ___________________________ **Date:** ______________ **Phone Number:** ____________________________

1 General Requirements and System Information

☐ Microinverter
Number of PV modules installed: __________
Number of Microinverters installed: __________

☐ AC Module (ACM)
Number of ACM's installed: __________
*Note: Listed Alternating-Current Module (ACM) is defined in **CEC 690.2** and installed per **CEC 690.6***

Number of Branch Circuits, 1, 2, 3, or 4: __________
Actual number of Microinverters or ACMs per branch circuit: 1. _________ **2.**__________ **3.**__________
Combined Microinverter or ACM output rating ((# of Microinverters or ACMs)*(AC inverter output power)) = _____ **W ≤ 10,000 W)**

1.1 Lowest expected ambient temperature for the location: (T_L) = __________ **^{o}C**
1.2 Average ambient high temperature for the location: (T_H) = __________ **^{o}C**
Provide the name of the source used to determine T_L and T_H: ____
____

2 Microinverter or ACM Information and Ratings

Microinverters with ungrounded DC inputs shall be installed in accordance with CEC 690.35.
Microinverter or ACM Manufacturer: _____________________________
Model: ____

2.1 Rated (continuous) AC output power: __________ **Watts**
2.2 Nominal AC Voltage Rating: __________ **Volts**
2.3 Rated (continuous) AC output current: __________ **Amps**

If installing ACMs, skip [STEPS 2.4 through 2.6]
2.4 Maximum DC Input Voltage Rating: __________ **Volts**
2.5 Maximum DC Input Current Rating: __________ **Amps**
2.6 Maximum DC Input Short Circuit Current Rating: __________ **Amps (if provided by manufacturer)**

3 PV Module Information

(If installing ACMs, skip to [STEP 6])

PV Module Manufacturer: ____
Model: ____
3.1 Module DC output power under standard test conditions (STC) = __________ **Watts**

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3.2 Module V_{OC} at STC (from module nameplate): __________ Volts
3.3 Module I_{SC} at STC (from module nameplate): __________ Amps

4 PV Module Maximum DC Voltage

(If installing ACMs, skip to [STEP 6])

Maximum DC voltage shall not exceed inverter manufacturer's maximum input voltage rating **[STEP 2.4]** __________ Volts. If the open-circuit voltage (V_{OC} from **[STEP 3.2]**) temperature coefficients (β or ε) are provided by the module manufacturer, use the calculation in **Method 1.** If V_{OC} temperature coefficient is not provided by the module manufacturer, use the calculation in **Method 2**.

4.1 Method 1:

V_{OC} temperature coefficient (β)= __________ %/^{O}C
Max number of modules per inverter __________ × {V_{OC} + [(T_L-25) × (β × V_{OC})/100]} = __________ Volts

If module manufacturer provides a voltage temperature coefficient (ε) in mV/°C, use the formula below.
V_{OC} temperature coefficient (ε)= __________ mV/^{O}C
Max number of modules per inverter __________ × {V_{OC} + [(T_L-25) × (ε/1000)]} = __________ Volts

4.2 Method 2:

Maximum number of modules per inverter __________ x V_{OC} __________ x K_T = __________ Volts,
Where K_T= ________ is a correction factor for ambient temperatures below 25 °C. See **Table 690.7**.

Verify the Low Temperature V_{OC} is less than the Microinverter maximum input voltage from **[STEP 2.4]**: □ Yes □ No

5 PV Short Circuit Current

(If installing ACMs, skip to [STEP 6])

5.1 Calculate the Maximum Short Circuit Current for the PV module

Adjust the PV current for peak sunlight (x 1.25) and compare it to the microinverter Maximum DC Input Short Circuit Current Rating. (If Max DC Input Short Circuit Current rating is not provided by manufacturer, use 1.56 x Max DC Input rating (per UL 1741)):

5.1.1 Maximum Short Circuit Current = (PV Short Circuit Current, I_{SC}, from **[STEP 3.3])** * 1.25 = __________ Amps
5.1.2 Verify Maximum Short Circuit Current **[STEP 5.1.1]** is equal to or less than the Maximum DC Input Short Circuit Current **[STEP 2.6]** = __________ Amps or the Maximum DC Input Current **[STEP 2.5]** * 1.56 = __________ Amps

6 Branch and Combined Inverter Output Circuit Information and Calculations

Fill in **[Table 1]** to describe the Branch and Combined System circuits.

Circuit Power = (Number of Microinverters or ACMs) * (Rated AC output power **[STEP 2.1]**) = __________ Watts
Circuit Current = (Circuit Power) / (Nominal AC voltage **[STEP 2.2]**)) = __________ Amps

Table 1 - OCPD and Ampacity Current Calculations

	Branch 1	Branch 2	Branch 3	Branch 4	Combined Inverter Output Circuit
Number of Microinverters or ACMs					
AC Power for each unit **[STEP 2.1]**, Watts					
Circuit Power, Watts					
Nominal AC Voltage **[STEP 2.2]**, Volts					
Circuit Current, Amps					

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7 Sizing Branch and Combined Inverter Output Circuit Conductors

Calculate the current using both Method A **[STEP 7.1] and** Method B **[STEP 7.2] for each Branch and the Combined Inverter Output Circuit from [Table 1]. Enter the results in [Table 2].**

7.1 Method A:

7.1.1 Each Branch Circuit Current, Method A

(Number Microinverters/ACMs) * (AC power **[STEP 2.1]**) / (Nominal AC voltage **[STEP 2.2]**) x 1.25 = __________ Amps

7.1.2 Combined Inverter Output Circuit Current, Method A

(Total Number Microinverters/ACMs) * (AC power **[STEP 2.1]**) / (Nominal AC voltage **[STEP 2.2]**) x 1.25 = _________ Amps

7.2 Method B:

Number of current-carrying branch and combined output circuit conductors in each raceway: ____________.

Each Raceway height above the roof: ____________ inches (if not applicable indicate N/A)

The correction factors for each raceway:

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 **Table 310.15(B)(3)(c)** and **Table 310.15(B)(2)(a).**

7.2.1 Each Branch Circuit Current, Method B

(Number Microinverters/ACMs) * (AC power **[STEP 2.1]**) ____ / (Nominal AC voltage **[STEP 2.2]**) ____ / (C_F x C_T) _____= ___ Amps

7.2.2 Combined Inverter Output Circuit Current, Method B

(Total Number Microinverters/ACMs) * (AC power **[STEP 2.1]**) ___/(Nominal AC voltage **[STEP 2.2]**) ____/ (C_F x C_T) ___= ___ Amps

7.3 Determine Conductor Size

Using the greater ampacity as calculated in **Method A** or **Method B**, use **Table 310.15(B)(16)** to identify the 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 (typically 60°C or 75°C).

Table 2 – Branch and Combined Circuit Currents, Correction Factors, and Conductor Sizes

	Branch 1	Branch 2	Branch 3	Branch 4	Combined Inverter Output Circuit
7.1 Method A: Branch and Combined Circuit Current					
7.2 Method B: Number of current carrying conductors for Branch and Combined Circuit Current					
7.2 Method B: Raceway height above the roof					
7.2 Method B: C_F					
7.2 Method B: C_T					
7.2 Method B: Branch and Combined Circuit Current					
Minimum Conductor Size, AWG					

8 Branch and Combined Inverter Output Circuit OCPD Size

Determine the OCPD size for each Branch Circuit and for the Combined Inverter Output Circuit. Use **CEC 690.9(B)** to determine the OCPD size. Enter the results in Branch and Inverter Output circuit current from **STEP 7.1** or**7.2** in **Row # 1 of Table 3** and OCPD sizes in **Row # 2 of Table 3**.

8.1.1 Each Branch Circuit Current OCPD Size

(Number Microinverters/ACMs) ____ * (AC power **[STEP 2.1]**) _____ / (Nominal AC voltage **[STEP 2.2]**) _____ x 1.25= _____ Amps

8.1.2 Combined Inverter Output Circuit Current OCPD Size

(Total Number Microinverters/ACMs) ___* (AC power **[STEP 2.1]**) ____ / (Nominal AC voltage **[STEP 2.2]**) ____ x 1.25 = _____ Amps

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Size the inverter output OCPD based on the value calculated above. Where the figure is between two standard values of fuse/breaker sizes (see **CEC 240.6(A)**), the next higher size may be used provided the conductors are sufficiently sized. The OCPD's rating may not exceed the conductor ampacity or the inverter manufacturer's max OCPD rating for the inverter.

Table 3 - Branch and Combined Inverter Output Circuit OCPD Sizing

#		Branch 1	Branch 2	Branch 3	Branch 4	Combined Inverter Output Circuit
1	Branch and Inverter Output Circuit Current, Amps					
2	Branch and Inverter Output OCPD, Amps					

9 Subpanel (if used)

The sum of the ampere ratings as determined below **[STEP 9.2 or 9.3]** shall not exceed 100% percent of the rating of the busbar or the supply conductor **[CEC 705.12(D)(2)(a) or (c)]**.

9.1 Subpanel busbar rating: __________ Amps ≤ 125 Amps

9.2 Using **[Row #1 of Table 3]**, (Sum of all inverter output Branch circuit currents) ________ Amps + (Busbar OCPD) ________ Amps = __________ Amps ≤ 100% of **[STEP 9.1]** Amps **[CEC 705.12(D)(2)(a)]**. Or

9.3 Using **[Row #2 of Table 3]**, (Sum of all inverter output Branch OCPDs) __________ Amps + (Sum of all Load Branch circuit OCPDs) __________ Amps = __________ Amps ≤ 100% of **[STEP 9.1]** Amps **[CEC 705.12(D)(2)(c)]**.

10 Point of Connection to Utility:

One of the following methods of interconnection must be utilized.

10.1 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 connected to power production sources shall not exceed the rating of the service**. The connection shall not compromise listing or integrity of any equipment.

10.2 Load Side Connection: □ Yes □ No (If No, the connection must be supply side connected).

If **Yes, Is the PV OCPD positioned at the opposite end from input feeder location or main OCPD location? □ Yes □ No**

If No, the sum of the selected ampere ratings (not including the 125% of inverter output current rating (Amps)) as shown below **[Table 4, 3rd or 4th Row]** shall not exceed 100% percent of the rating of the busbar or conductor **[CEC 705.12(D)(2)(a) or (c)]**. Circle the corresponding values for the Busbar size and Main OCPD for the 100% application

If Yes, circle the corresponding values of the Busbar size and Main OCPD for the use of 120% multiplier application **[CEC 705.12(D)(2)(b)]**, and attached service load calculation per Article 220 of Los Angles Electrical Code.

Per **705.12(D)(2)(b)**: [Inverter output OCPD size **[Table 3]** + Main OCPD Size] ≤ [Bus size x (120%)]

Table 4 - Maximum Combined Inverter Output Circuit OCPD, CEC 705.12(D)(2)

Busbar Size (Amps)	**100**	**125**	**125**	**200**	**200**	**200**	**225**	**225**	**225**
Main OCPD (Amps)	**100**	**100**	**125**	**150**	**175**	**200**	**175**	**200**	**225**
Combined Inverter Output Circuit Current with 100% of busbar rating (Amps)	0	20	0	40	20	0	40	20	0
Maximum Combined Inverter OCPD with 100% of busbar rating (Amps)	0	25	0	50	25	0	50	25	0
Maximum Combined Inverter OCPD with 120% of busbar rating (Amps)	20	50	25	60†	60†	40	60†	60†	45

† This plan limits the maximum system size to 10 kw or less, therefore the combined OCPD size is limited to 60 A. If the main breaker is reduced, a load calculation per Article 220 must accompany the Standard Plans to show that the reduction is allowed.

All panelboard busbar ratings must comply with **CEC 705.12(D)(2)**.

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11 Rapid Shutdown

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 AC disconnect, inverter branch circuit disconnecting means (circuit breaker), 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.**

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

□ ACM or Microinverter mounted within, 3 m (10 ft) for exterior wiring, or 1.5 m (5 ft) for interior wiring, of the PV system. Reduction of the voltage for the inverter output circuit 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.

□ ACM or Microinverter mounted within, 3 m (10 ft) for exterior wiring, or 1.5 m (5 ft) for interior wiring, of the PV modules. A remotely-controlled AC disconnecting means is required immediately adjacent to or as close as practicable to the inverter's output and located within 10 feet of the array.

12 Grounding and Bonding

Check one of the boxes for whether system is grounded or ungrounded: □ Grounded, □Ungrounded.
For Microinverters with a grounded DC input, systems must follow the requirements of GEC (CEC 690.47) and EGC (CEC 690.43).
For ACM systems and Microinverters with ungrounded a DC input follow the EGC requirements of (CEC 690.43).

12.1 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. The DC EGC leaving the array and the AC EGC must be contained within the same raceway or cable or otherwise run with the circuit conductors serving the array per 690.43(F), 690.43(A), and 250.134(B).

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).

12.2 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).

12.3 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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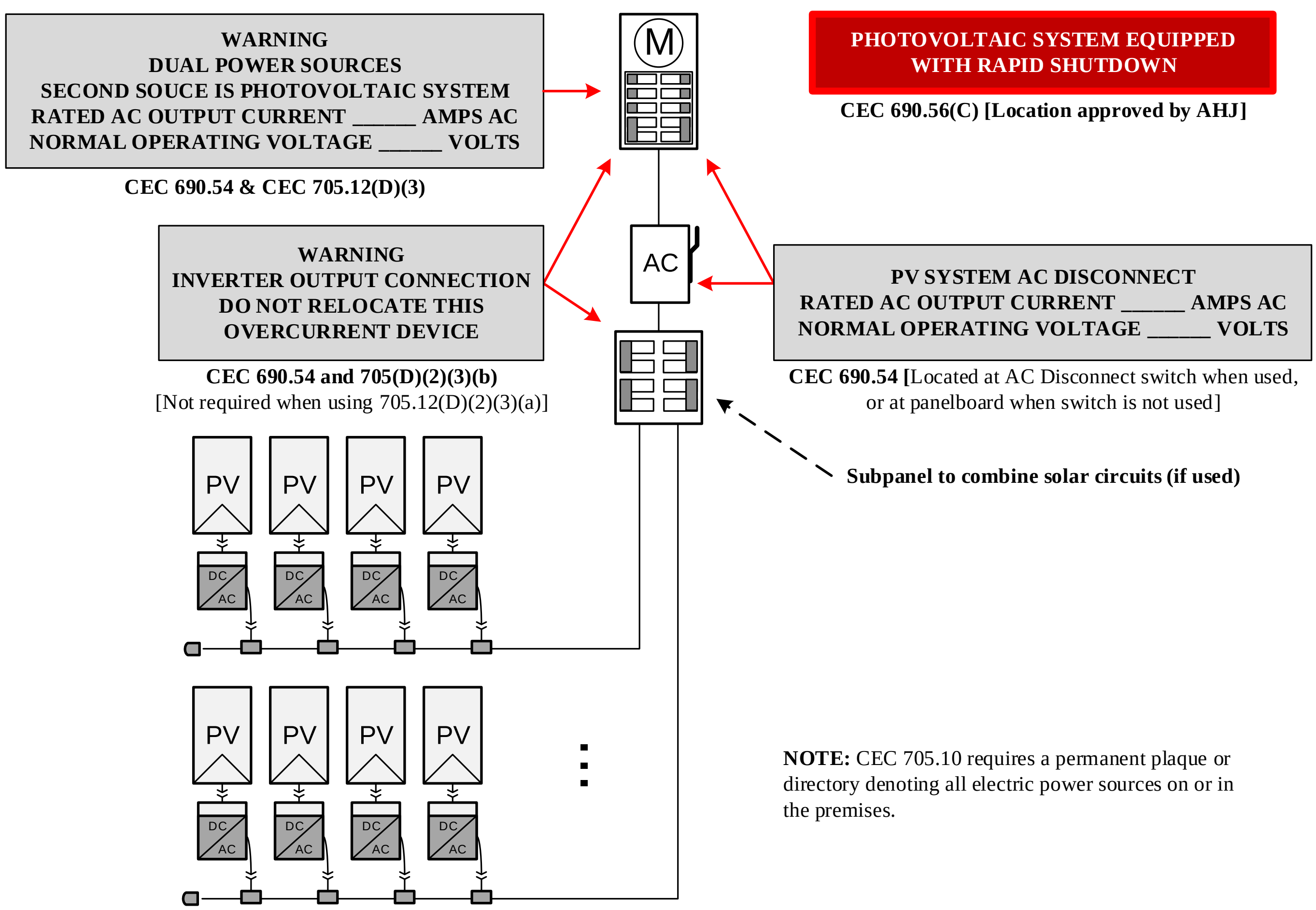
13 Markings

Per Section **CEC 690.54**, a permanent label shall be installed at an accessible location at the PV AC disconnecting means that shall indicate the following:

Rated AC Output current (total Combined System Current from [Table 1]) _______ Amps

13.1 Nominal Operating AC Voltage **[STEP 2.2]** __________ Volts

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



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.

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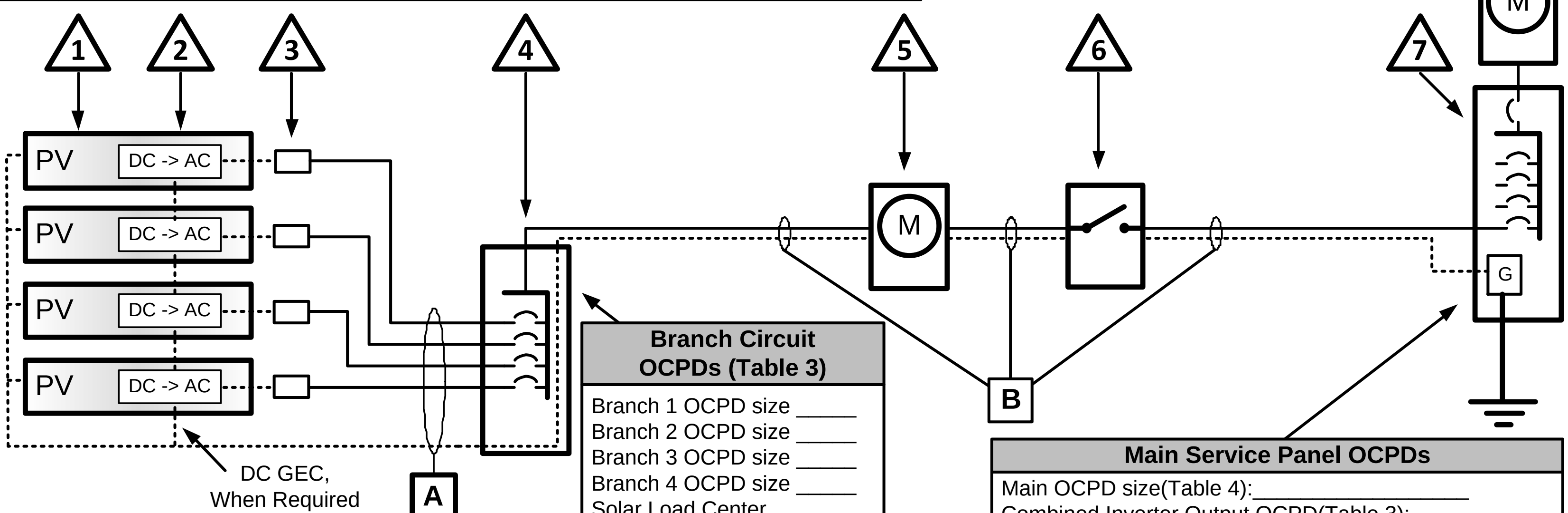
14 Microinverter/ACM Single Line Diagram

Equipment Schedule	
△ TAG	DESCRIPTION: (provide model number and description)
1	Solar PV Module or ACM:
2	Microinverter (if not ACM):
3	Junction Box(es):
4	Solar Load Center, Yes / No:
5	Performance Meter, Yes / No:
6	*Utility External Disconnect Switch Yes / No:
7	Main Electrical Service Panel

Single-Line Diagram for Microinverters or ACMs

Check a box for dc system grounding: ☐ Grounded, ☐ Ungrounded
For ungrounded dc power systems, EGC is required
For grounded dc power systems, GEC & EGC are required
Refer to CEC 250.120 for EGC installation & Table 250.122 for sizing

* Consult with your local AHJ and /or Utility



Branch Circuit OCPDs (Table 3)

Branch 1 OCPD size _____
Branch 2 OCPD size _____
Branch 3 OCPD size _____
Branch 4 OCPD size _____
Solar Load Center
Busbar (Sec. 10) ______

Main Service Panel OCPDs

Main OCPD size(Table 4):_________________
Combined Inverter Output OCPD(Table 3): ___________
Main Service Panel Busbar(Table 4): __________

Conductor, Cable and Conduit Schedule					
☐ TAG	Description and Conductor Type: (Table 2)	Conductor Size	Number of Conductors	Conduit/ Conductor/ Cable Type	Conduit Size
A	Current-Carrying Conductors: (for each branch circuit)				
	EGC:				
	GEC (when required):				
B	Current-Carrying Conductors:				
	EGC:				
	GEC (when required):				

Plan Reviewer Initials: ______