SOLAR PV STANDARD ELECTRICAL PLAN

Central Inverter Systems for Single Family Dwellings

glendale Community Development

***** Provide this document to the inspector along with ALL system installation instructions *****

Project Address: _____

Permit Number: _____

Scope: **Standard plan for installation of solar PV systems utilizing 2 wire multiple string central inverters, not exceeding a total AC output of 10kW, in single family dwellings having a 3 wire electrical service not larger than 225 amps at a voltage of 120/240. This plan covers Crystalline and Multi-Crystalline type modules where all the modules are mounted on the roof of the single family dwelling. For installations exceeding this scope, Electrical Plan review is required.**

NOTE: This plan is intended for use with standard DC to AC inverters containing an isolation transformer. This plan is NOT intended to be used with micro inverters or transformer-less inverters and is limited to installations where the DC system voltage does not exceed 600 volts. This plan is not intended for systems containing batteries or power optimizer. This document addresses only the requirements of the 2010 California Electrical Code (CEC), refer to other toolkit documents for California Residential code (CRC) requirements.

Installer information:

Name:	Phone Number: ( ) -
Address: _____ City: _____ State: _____ Zip _____	Homeowner: ☐ Contractor: ☐ Contractor License # _____ License type _____

Required information for DC wiring:

1. Total number of solar modules being installed: ☐	2. Number of modules per string: ☐
3. How many strings total? ☐	4. Are any strings wired in parallel? ☐ Yes ☐ No If "Yes", how many are paralleled together? ☐ Two _____ ☐ Other (specify) _____
5. Are you installing a combiner box with fuses? ☐ Yes ☐ No (If Yes, include calculation in Step # 13)	
6. Module Voc (from module nameplate): ☐	7. Module Isc (from module nameplate): ☐
8. Module maximum fuse or circuit breaker size (from module nameplate): ☐	9. Temperature correction factor from **Table 690.7** of the 2010 CEC. Varies by location. (Check with the local building department for this figure) _____

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10. Calculate the maximum DC system voltage (Shall not exceed the inverter maximum DC input voltage and shall not exceed 600 volts):

Maximum number of modules per string _____ x Voc _____ x temperature correction factor _____ = _____ volts

Note: This formula is intended to provide a close approximation of the maximum DC system voltage possible at the job location under the lowest ambient temperature condition. This result will always be slightly higher than when using the module manufacturer supplied temperature coefficient. The intent is to alert the installer that the 600 volt limit is close to being exceeded and is not intended to provide as accurate a result as the calculation employing the manufacturer supplied coefficient. Where the installer chooses to use the manufacturer's supplied coefficient, approval by the local enforcing agency is required.

11. Calculate the maximum DC current per string to allow for peak sunlight conditions and continuous operation in excess of three hours:

Module Isc _____ x 1.56 = _____ **Max amps carried by the conductor.**

12. **Choosing a conductor size for the DC source circuits & output circuit:**
Where Type USE-2 or other listed PV conductors are run in free air from the module locations to a junction box or combiner box, the minimum size permitted shall be #12 AWG per the module manufacturers' installation instructions and the conductor material shall be copper.

If any part of the wiring from the modules to the combiner box or inverter is to be installed in a raceway, reductions in the amount of current the conductors can carry may have to be made. Conductors to be installed in a raceway shall be Type THWN-2 or equivalent and the conductor material shall be copper.

To select the correct conductor size for the PV source circuits from the modules to the combiner box or to the inverter, go to Table A on page 4. Select how many conductors you will have in the raceway and how high above the roof surface the raceway will be mounted. Using the appropriate "Ambient Temperature" section for the job location, select the number from the column in Table A that matches the result you entered in item #11. (The number in Table A may be the same or larger than the number in item #11, **but it shall not be less**). Move to the top of the column to see the minimum size conductor needed for this part of the installation. Enter the number here for the **Source Circuit conductor size**: **# _____ AWG.**

Note: Per Section 338.12(B)(1), USE-2 shall not be used for interior wiring.

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13. If a combiner box is to be installed to connect the string circuits together, then the size of the "Output circuit" conductors from the combiner to the inverter must be determined.
    To do this, multiply the number of strings that are to be combined (from item #3) with the "Max amps" (from item #11) _____ x _____ = _____ Amps. Using Table A, repeat the process used to select the conductor size for the source circuits and enter the number here for **Output Circuit conductor size: #** _____ **AWG.** (If no combiner box, enter N/A)

14. Where a combiner box is installed, or where more than two strings of modules are electrically connected together in "parallel", each individual string shall be protected by its own over current protection or feeders to be sized for sum of all short circuit current of all strings. The fuse or breaker shall be listed as being suitable for use in a DC circuit and shall meet or exceed the maximum voltage of the circuit. The rating of the fuse or circuit breaker shall not be larger than the maximum size specified on the lowest rated module in the string. All combiner boxes shall be listed by a recognized listting agency and labeled as such.
    Max fuse / breaker size permitted (from step #8) _____ **A.** **Fuse / breaker size installed** _____ **A.**

    Note: Where the module specifies "Max fuse size" a circuit breaker shall not be substituted. Where the module specifies "Max overcurrent protective device" (Max OCPD), then either a fuse or DC rated circuit breaker may be used.

NOTE: Per **Section 690.31 (E),** DC wiring can only be run inside of the house if it is installed in a listed **metallic raceway or enclosure**.

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Table A

Table A is based on the following:

A. Table 310.16 - Allowable Ampacity of Insulated Conductors, 90 C rated conductors.
B. Table 310.16 - Correction Factors based on temperature ranges.
C. Table 310.15(B)(2)(c) - Ambient Temperature Adjustments for Conduits Exposed to Sunlight On or Above Rooftops.
D. Table 310.15(B)(2)(a) Adjustment Factors for More Than Three Current-Carrying Conductors in a Raceway or Cable.
E. Sections 240.4(D)(5) and 240.4(D)(7) for 10 AWG and 12 AWG conductors

Table A: Maximum Allowable Ampacity of Conductors Installed in a Circular Raceway, Exposed to Sunlight, On or Above Rooftops

Number of Current Carrying Conductors in a Raceway	Height Above Rooftop	Highest Ambient Temp									
		Less than 30°C					30°C to 35°C				
		12 AWG	10 AWG	8 AWG	6 AWG	4 AWG	12 AWG	10 AWG	8 AWG	6 AWG	4 AWG
Up to 3 Conductors	0 to 0.5"	17	23	32	44	55	17	23	32	44	55
	above 0.5" to 3.5"	20	30	42	57	72	20	28	39	53	67
	above 3.5" to 12"	20	30	45	62	78	20	30	42	57	72
	above 12"	20	30	48	65	83	20	30	45	62	78
4 to 6 Conductors	0 to 0.5"	14	19	26	35	44	14	19	26	35	44
	above 0.5" to 3.5"	18	24	33	46	58	17	23	31	43	54
	above 3.5" to 12"	20	26	36	49	62	18	24	33	46	58
	above 12"	20	28	38	52	66	20	26	36	49	62
7 to 9 Conductors	0 to 0.5"	12	16	22	30	39	12	16	22	30	39
	above 0.5" to 3.5"	16	21	29	40	51	15	20	27	37	47
	above 3.5" to 12"	17	23	32	43	55	16	21	29	40	51
	above 12"	18	24	33	46	58	17	23	32	43	55
10 to 20 Conductors	0 to 0.5"	9	12	16	22	28	9	12	16	22	28
	above 0.5" to 3.5"	11	15	21	29	36	11	14	20	27	34
	above 3.5" to 12"	12	16	23	31	39	11	15	21	29	36
	above 12"	13	17	24	33	41	12	16	23	31	39
		35°C to 40°C					40°C to 45°C				
Up to 3 Conductors	0 to 0.5"	12	16	23	31	39	12	16	23	31	39
	above 0.5" to 3.5"	17	23	32	44	55	17	23	32	44	55
	above 3.5" to 12"	20	28	39	53	67	17	23	32	44	55
	above 12"	20	30	42	57	72	20	28	39	53	67
4 to 6 Conductors	0 to 0.5"	10	13	18	25	31	10	13	18	25	31
	above 0.5" to 3.5"	14	19	26	35	44	14	19	26	35	44
	above 3.5" to 12"	17	23	31	43	54	14	19	26	35	44
	above 12"	18	24	33	46	58	17	23	31	43	54
7 to 9 Conductors	0 to 0.5"	9	11	16	22	27	9	11	16	22	27
	above 0.5" to 3.5"	12	16	22	30	39	12	16	22	30	39
	above 3.5" to 12"	15	20	27	37	47	12	16	22	30	39
	above 12"	16	21	29	40	51	15	20	27	37	47
10 to 20 Conductors	0 to 0.5"	6	8	11	15	19	6	8	11	15	19
	above 0.5" to 3.5"	9	12	16	22	28	9	12	16	22	28
	above 3.5" to 12"	11	14	20	27	34	9	12	16	22	28
	above 12"	11	15	21	29	36	11	14	20	27	34
		45°C to 50°C					50°C to 55°C				
Up to 3 Conductors	0 to 0.5"	0	0	0	0	0	0	0	0	0	0
	above 0.5" to 3.5"	12	16	23	31	39	12	16	23	31	39
	above 3.5" to 12"	17	23	32	44	55	12	16	23	31	39
	above 12"	17	23	32	44	55	17	23	32	44	55
4 to 6 Conductors	0 to 0.5"	0	0	0	0	0	0	0	0	0	0
	above 0.5" to 3.5"	10	13	18	25	31	10	13	18	25	31
	above 3.5" to 12"	14	19	26	35	44	10	13	18	25	31
	above 12"	14	19	26	35	44	14	19	26	35	44
7 to 9 Conductors	0 to 0.5"	0	0	0	0	0	0	0	0	0	0
	above 0.5" to 3.5"	9	11	16	22	27	9	11	16	22	27
	above 3.5" to 12"	12	16	22	30	39	9	11	16	22	27
	above 12"	12	16	22	30	39	12	16	22	30	39
10 to 20 Conductors	0 to 0.5"	0	0	0	0	0	0	0	0	0	0
	above 0.5" to 3.5"	6	8	11	15	19	6	8	11	15	19
	above 3.5" to 12"	9	12	16	22	28	6	8	11	15	19
	above 12"	9	12	16	22	28	9	12	16	22	28

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Grounding the DC side of the inverter:

A minimum #8 copper Grounding Electrode conductor must be run un-spliced from the factory identified system grounding terminal of the inverter to the grounding electrode system of the house. The grounding electrode system may consist of one or more of the following: Ground rod(s), Ufer ground, or metallic water pipe with a minimum of 10 feet in the ground. (**Section 690.47)**

AC wiring information:

15. The inverter shall be listed and labeled by a recognized testing agency and be identified as "Utility interactive". Ground fault protection (GFP) shall comply with **Section 690.5** 2010 CEC.

    Specify inverter: Make _____ Model # _____ Elec rating _____ kW

16. Per **Section 690.9** 2010 CEC, each inverter shall be protected by an overcurrent device on the AC output side of the inverter. This can be a fuse or a circuit breaker. To correctly size the overcurrent device, locate the maximum AC output of the inverter (in amps) on the inverter nameplate, and multiply by 1.25 (This is required because the unit will be in continuous use for more than three hours).
    Maximum AC output current _____ x **1.25 = _____ Amps.** (This number will also be used to size the inverter output circuit conductors.)
    Where the "Maximum AC output" is shown only in Watts, divide that number by 240 and then multiply by 1.25 to get the correct size breaker or fuse.
    If the maximum AC output is between standard breaker or fuse sizes, the next higher size can be used so long as the inverter output conductors are sized sufficiently large enough for the amount of current produced by the inverter. **Important note:** Where a fused disconnect switch is installed, the output conductors from the inverter will connect to the **"LOAD"** side (**bottom**) terminals of the switch and the wiring from the utility will connect to the **"LINE"** side (**top**) terminals. This meets the requirement of **Section 404.6(C)** and will reduce the risk of electrical shock hazards when changing a fuse with the system still energized by the utility electrical supply.

17. Many utility providers require a performance meter and a safety disconnect switch to be installed between the PV power source and their equipment. This means that the AC power output from the inverter(s) may not connect directly into the electrical panel of the house. For a single inverter, the output from the inverter disconnect switch will connect to the performance meter (if required). Where multiple central inverters are installed, they will usually go first to a solar load center. This is just a standard circuit breaker panel that collects together the output circuits from the individual inverters. Each inverter will have its own circuit breaker. The size of each circuit breaker will be determined from step #16. From this panel one feeder will go to the performance meter, then to the safety disconnect switch and lastly to the point of interconnection at the house electrical panel. No electrical loads shall be connected between the output of the inverter and the connection to the house electrical panel. Contact your local utilities for performance meter and AC utility disconnect switch requirements.

18. Where a performance meter is required by the local utility to record the power produced by the PV system, the output wiring from the inverter shall always connect to the **"LINE"** side terminals of the meter.

19. Where disconnect switches (with or without fuses) are installed in the circuit from the inverter output terminals to the house electrical panel, the wiring originating at the inverter(s) shall always connect to the **"LOAD"** side terminals of **ANY** disconnect that has been installed

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20. The connection to the breaker panel **shall** be through a dedicated circuit breaker that connects to the panel bus bars in an approved manner. "Load Side Taps" where the inverter AC wiring does not terminate using a dedicated breaker or set of fuses are prohibited under **ANY** condition by **Section 690.64 (B)**.

21. Per Section 690.64(B)(2), the sum of all overcurrent protective devices supplying power to the busbar or conductor shall not exceed 120% of their rating. In most PV installations, the breakers feeding the busbar are the main breaker and the backfed PV breaker. Per Section 690.64(B)(7), to utilize the 120% rule, the PV backfed breaker must be at the opposite end of the main breaker location. For a 100 amp rated bus, this means that the main breaker and the PV backfed breaker shall not add up to more than 120 amps. For a 200 amp rated bus, the combined ampacity of the two breakers (the main breaker and the PV breaker) shall not exceed 240 amps and so on. The location of the PV backfed breaker must be identified per 690.64(B)(7) with the following verbiage: "WARNING INVERTER OUTPUT CONNECTION. DO NOT RELOCATE THE OVERCURRENT DEVICE."

    Where it is not possible to locate the breakers at opposite ends of the panel bus, the sum of the two breakers is not permitted to exceed 100% of the bus rating.

    Note: In some cases it may be possible to reduce the size of the main circuit breaker to accommodate the addition of a PV breaker and still not exceed the bus bar rating. This requires that a "load calculation" of the house electrical power consumption be made in order to see if this is an acceptable solution.

22. Per **Section 690.53**, a permanent label for the DC power source shall be installed at the PV DC disconnecting means. This label shall show the following: (a) Rated maximum power-point current, (b) Rated maximum power-point voltage, (c) Maximum system voltage, (d) Short circuit current of the PV system.

    (a) **Rated maximum power-point current (mppA)** (this is the actual current in amps produced by the PV system). Multiply the **Imax** value from the module nameplate by the number of strings in the system.
    Imax _____ x **# of strings** _____ = _____ **Amps**.

    (b) **Rated maximum power-point voltage (mppV)** (this is the highest operating voltage of the PV system). Multiply the **Vmax** value from the module nameplate by the number of modules in the **largest** string.
    Vmax _____ x **# of modules** _____ **=** _____ **Volts.**

    (c) **Maximum system voltage** (see step #10) _____ **Volts**

    (d) **Short circuit current** of the PV system (module Isc from step #7 x 1.25). **Isc** _____ x **1.25** = _____ **Amps**.

    Note: 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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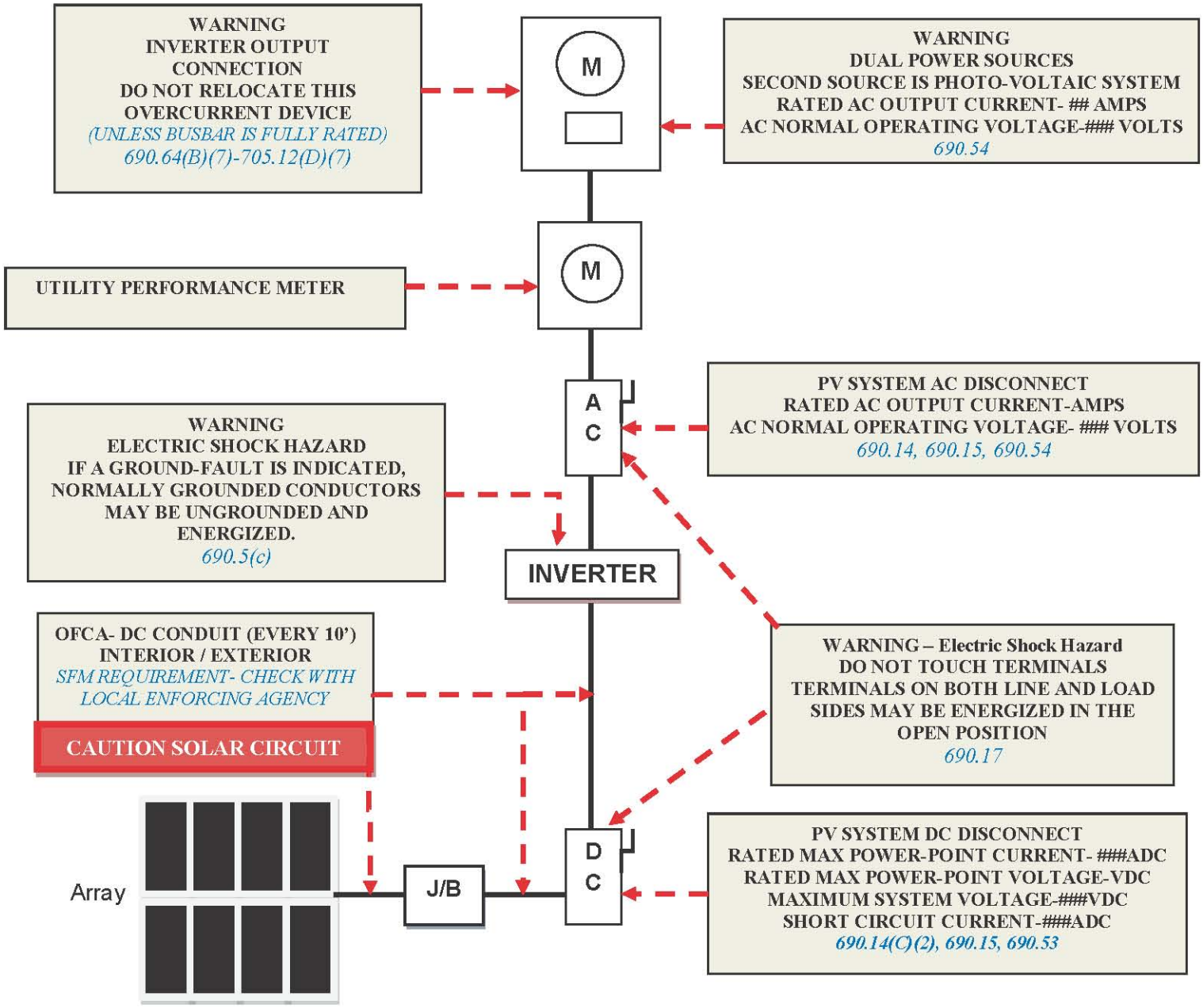
23. The following signage is required to be installed:

(a) Per **Section 690.17** 2010 CEC, where both the line and load side terminals of any disconnect may be live in the "OFF" position the following warning shall be placed on the front of the disconnect "WARNING LINE AND LOAD TERMINALS MAY BE ENERGIZED IN THE OPEN POSITION".



Note: Italicized text shown inside the boxes is not required to be part of the sign, it is only for reference.

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SOLAR PV STANDARD PLAN

Central Inverter Systems for Single Family Dwellings

TAG	DESCRIPTION
1	SOLAR PV MODULE
2	DC PV SOURCE CIRCUIT
3	COMBINER BOX (if installed), refer to item 14 on page 3
4	DC DISCONNECT
5	DC PV OUTPUT CIRCUIT
6	DC EQUIPMENT GROUNDING CONDUCTOR per 690.43 NEC
7	INVERTER DC DISCONNECT
8	DC TO AC INVERTER WITH ISOLATION TRANSFORMER
9	GROUND FAULT DETECTION INTERRUPTER
10	SOLAR LOAD CENTER (If installed)
11	UTILITY SAFETY SWITCH
12	UTILITY PERFORMANCE METER
13	INVERTER DC GROUNDING ELECTRODE CONDUCTOR (MIN #8 AWG COPPER)
14	ELECTRICAL SERVICE PANEL

STANDARD PV PLAN FOR SINGLE FAMILY DWELLING
CENTRAL INVERTER

MAXIMUM 10 KW
MAXIMUM 225 AMP SERVICE

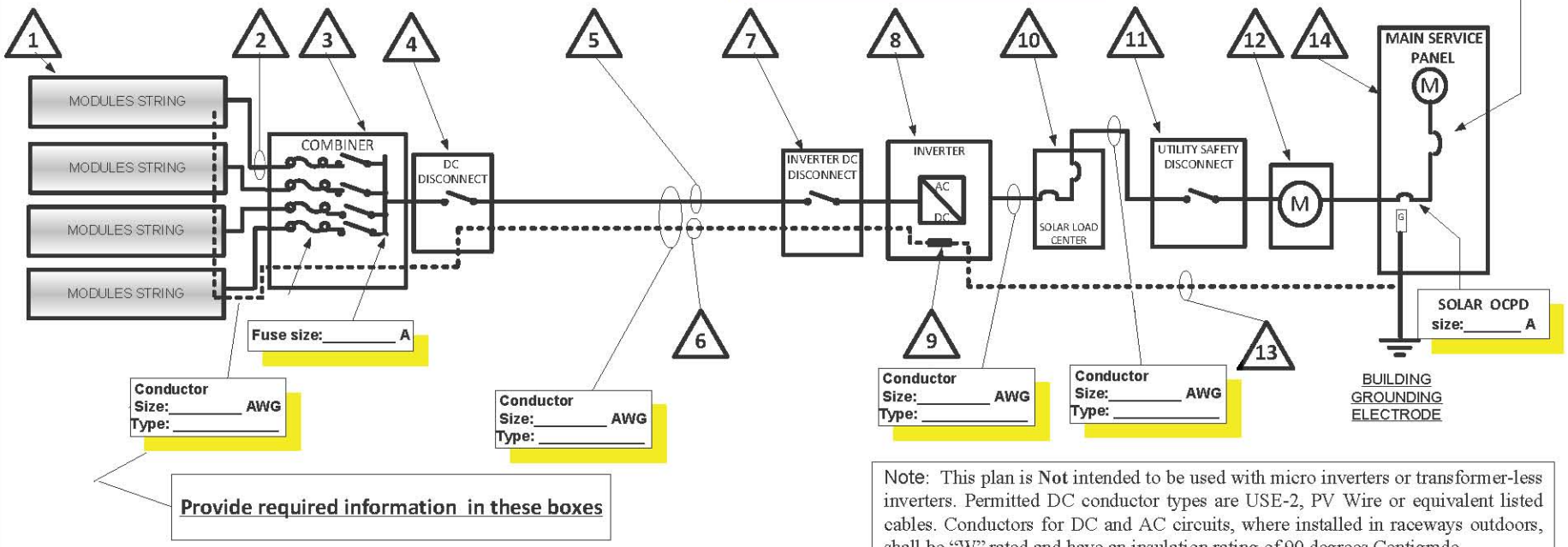
THIS PLAN MUST BE PROVIDED TO THE FIELD INSPECTOR

MAIN BREAKER / FUSE Size:_____A

SOLAR BREAKER/ FUSE Size:_____A

MAIN PANEL BUS Size:_____ A

MAIN OVERCURRENT PROTECTIVE DEVICE size:_____ A



Conductor Size:_____ AWG Type: _____

Conductor Size:_____ AWG Type: _____

Conductor Size:_____ AWG Type: _____

Conductor Size:_____ AWG Type: _____

Provide required information in these boxes

Note: This plan is **Not** intended to be used with micro inverters or transformer-less inverters. Permitted DC conductor types are USE-2, PV Wire or equivalent listed cables. Conductors for DC and AC circuits, where installed in raceways outdoors, shall be "W" rated and have an insulation rating of 90 degrees Centigrade.

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SOLAR PV STANDARD PLAN

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ROOF PLAN

PROVIDE A ROOF PLAN SHOWING LOCATION OF ALL EQUIPMENT, DISCONNECTING MEANS AND REQUIRED CLEARANCES.

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