

PROCEDURES FOR SOLAR ELECTRIC (PHOTOVOLTAIC abbreviated as PV) SYSTEM DESIGN AND INSTALLATION

SECTION 4: SOLAR ELECTRIC (PV) SYSTEM INSTALLATION CHECKLIST

Following the completion of each item on the checklist below, check the box to the left of the item and insert the date and initials of the person completing the item. Stars (*) denote items that should be checked directly by the field superintendent with the installing contractor.

Before starting any PV system testing: (hard hat and eye protection required)

- 1. _____ Check that non-current carrying metal parts are grounded properly (array frames, metal boxes, etc. are connected to the grounding system).
- 2. _____ Ensure that all labels and safety signs specified in the plans are in place.
- 3. _____ Verify that all disconnect switches (from the main AC disconnect all the way through to the combiner fuse switches) are in the open position and tag each box with a warning sign to signify that work on the PV system is in progress.

PV ARRAY—General (hard hat, gloves, and eye protection required)

- 1. _____ Verify that all combiner fuses are removed and that no voltage is present at the output of the combiner box.
- *2. _____ Visually inspect any plug and receptacle connectors between the modules and panels to ensure they are fully engaged.
- *3. _____ Check that strain reliefs/cable clamps are properly installed on all cables and cords by pulling on cables to verify.
- *4. _____ Check to make sure all panels are attached properly to their mounting brackets and nothing catches the eye as being abnormal or misaligned.
- *5. _____ Visually inspect the array for cracked modules.
- *6. _____ Check to see that all wiring is neat and well supported.

PV ARRAY CIRCUIT WIRING (hard hat and eye protection required)

- 1. _____ Check home run wires (from PV modules to combiner box) at DC string combiner box to ensure there is no voltage on them.

- 2. _____ Recheck that fuses are removed and all switches are open.
- 3. _____ Connect the home run wires to the DC string combiner box terminals in the proper order and make sure labeling is clearly visible.

REPETITIVE SOURCE CIRCUIT STRING WIRING (hard hat, gloves, and eye protection, required) (The following procedure must be followed for each source circuit string in a systematic approach—(i.e. east to west or north to south).) Ideal testing conditions are midday on cloudless days March through October.

- 4. _____ Check open-circuit voltage of each of the panels in the string being wired to verify that it provides the manufacturer's specified voltage in full sun. (Panels under the same sunlight conditions should have similar voltages--beware of a 20 Volt or more shift under the same sunlight conditions.)
- 5. _____ Verify that the both the positive and negative string connectors are identified properly with permanent wire marking.
- 6. _____ Repeat this sequence for all source circuit strings.

CONTINUATION OF PV ARRAY CIRCUIT WIRING (hard hat, gloves, and eye protection required)

- 7. _____ Recheck that DC Disconnect switch is open and tag is still intact.
- 8. _____ **VERIFY POLARITY OF EACH SOURCE CIRCUIT STRING** in the DC String Combiner Box (place common lead on the negative grounding block and the positive on each string connection--pay particular attention to make sure there is NEVER a negative measurement). Verify open-circuit voltage is within proper range according to manufacturers installation manual and number each string and note string position on as-built drawing. (voltages should match closely if sunlight is consistent)

NOTE: IF POLARITY OF ONE SOURCE CIRCUIT STRING IS REVERSED, THIS CAN START A FIRE IN THE FUSE BLOCK RESULTING IN THE DESTRUCTION OF THE COMBINER BOX AND POSSIBLY ADJACENT EQUIPMENT. REVERSE POLARITY ON AN INVERTER CAN ALSO CAUSE DAMAGE THAT IS NOT COVERED UNDER THE EQUIPMENT WARRANTY.

- 9. _____ Retighten all terminals in the DC String Combiner Box.

WIRING TESTS--Remainder of System: (hard hat, gloves, and eye protection required)

- 10. _____ Verify that the only place where the AC neutral is grounded is at the main service panel.

- 11. _____ Check the AC line voltage at main AC disconnect is within proper limits (115-125 Volts AC for 120 Volts and 230-250 for 240 Volts).
- 12. _____ If installation contains additional AC disconnect switches, repeat the step 11 voltage check on each switch working from the main service entrance to the inverter AC disconnect switch, closing each switch after the test is made except for the final switch before the inverter (it is possible that the system only has a single AC switch).

INVERTER STARTUP TESTS (hard hat, gloves, and eye protection required)

- 1. _____ Be sure that the inverter is off before proceeding with this section.
- 2. _____ Test the continuity of all DC fuses to be installed in the DC string combiner box, install all string fuses, and close fuse switches in combiner box.
- 3. _____ Check open circuit voltage at DC disconnect switch to ensure it is within proper limits according to the manufacturer's installation manual.
- 4. _____ If installation contains additional DC disconnect switches, repeat the step 4 voltage check on each switch working from the PV array to the inverter DC disconnect switch, closing each switch after the test is made except for the final switch before the inverter (it is possible that the system only has a single DC switch).
- *5. _____ At this point consult the inverter manual and follow proper startup procedure (all power to the inverter should be off at this time).
- *6. _____ Confirm that the inverter is operating and record the DC operating voltage here: _____.
- *7. _____ Confirm that the operating voltage is within proper limits according to the manufacturers installation manual.
- 8. _____ After recording the operating voltage at the inverter, close any open boxes related to the inverter system.
- *9. _____ Confirm that the inverter is producing the expected power output on the supplied meter.
- *10. _____ Provide the homeowner with the initial startup test report.

***SYSTEM ACCEPTANCE TEST (hard hat and eye protection required)**

Ideal testing conditions are midday on cloudless days March through October. However, this test procedure accounts for less than ideal conditions and allows acceptance tests to be conducted on sunny winter days.

- *1. _____ Check to make sure that the PV array is in full sun with no shading whatsoever. If it is impossible to find a time during the day when the whole array is in full sun, only that portion that is in full sun will be able to be accepted.

- *2. _____ If the system is not operating, turn the system on and allow it to run for 15 minutes before taking any performance measurements.

- *3. _____ Obtain solar irradiance measurement by one of two methods and record irradiance here: W/m^2 . To obtain percentage of peak sun divide irradiance by $1000 W/m^2$ and record the value here:
(example: $692 W/m^2 \div 1000 W/m^2 = 0.692$ or 69.2%.)
Method 1: Take measurement from calibrated solar meter or pyranometer.
Method 2: Place a single, properly operating PV module, of the same model found in the array, in full sun in the exact same orientation as the array being tested. After 15 minutes of full exposure, test the short circuit current with a digital multimeter and place that reading here: _____ Amps. Divide this number into the short circuit current (I_{sc}) value printed on the back of the PV module and multiply this number by $1000 W/m^2$ and record the value on the line above. (example: $I_{sc}\text{-measured} = 3.6$ Amps; $I_{sc}\text{-printed on module} = 5.2$ Amps; Irradiance = $3.6 \text{ Amps} / 5.2 \text{ Amps} * 1000 W/m^2 = 692 W/m^2$)

- *4. _____ Sum the total of the module ratings and place that total here: _____ $Watts_{STC}$. Multiply this number by 0.7 to obtain expected peak AC output and record here:
_____ $Watts_{AC\text{-estimated}}$.

- *5. _____ Record AC Watt output from the inverter or system meter and record here:
_____ $Watts_{AC\text{-measured}}$.

- *6. _____ Divide $Watts_{AC\text{-measured}}$ by percent peak irradiance and record here:
_____ $Watts_{AC\text{-corrected}}$. This "AC-corrected" value is the rated output of PV system. This number must be within 90% or higher of $Watts_{AC\text{-estimated}}$ recorded in step 4. If it is less than 90%, the PV system is either shaded, dirty, miswired, fuses are blown, or the modules or inverter are not operating properly.

Example Test:

A PV system is made up of 20, 100 $Watt_{STC}$ PV modules operating at an estimated irradiance of $692 W/m^2$ using method 2 shown above. The power output is measured to be 1000 $Watts_{AC\text{-measured}}$ at the time of the test. Is this system operating properly or not?

Example Solution:

Sum of module ratings = 100 Watts_{STC} per module x 20 modules = 2,000 Watts_{STC}.

Estimated AC power output = 2,000 Watts_{STC} x 0.7 = 1,400 Watts_{AC-estimated}.

Measured AC output = 1,000 Watts_{AC-measured}.

Corrected AC output = 1,020 Watts_{AC-corrected} ÷ 0.692 = 1,474 Watts_{AC-corrected}.

Comparison of corrected and estimated outputs: 1,474 Watts_{AC-corrected} ÷ 1,400 Watts_{AC-estimated} = 1.05, which is ≥ 0.9, demonstrating acceptable performance

Worksheet for PV System Field Inspection

One-line diagram comparison

_____ Is a one-line diagram available at the site?

_____ PV module model number matches plans and cut sheets

_____ PV modules are properly grounded with lugs on each module
or equivalent grounding method

_____ PV array wiring is consistent with plans (# of modules)

_____ Check that cable and conduit is properly supported

_____ Where plug connectors are used for module wiring, inspect a
sample to make sure that connectors are fully engaged

_____ Inverter model number matches plans and cut sheets

Structural Attachment of Array

_____ Confirm that footings and support structure match the supplied detail.

_____ Confirm that module attachment matches the supplied detail.

PV System Signs

_____ Do signs have sufficient durability to withstand the environment?

_____ Sign Identifying Photovoltaic Power Source (at DC disconnect)

_____ Operating current (provided in initial plan review)

_____ Operating voltage (provided in initial plan review)

_____ Maximum system voltage (690.7)

_____ Short-circuit current (690.8)

_____ Sign identifying AC point of connection (690.54)

_____ Maximum operating current (provided in initial plan review)

_____ Operating AC voltage (provided in initial plan review)

_____ Sign identifying switch for alternative power system

_____ Sign at the main service disconnect (702.8) notifying the type
and location of the optional standby system