SepiSolar

POWER BY DESIGN

PV Solar Project Evaluation Procedure and Case Study

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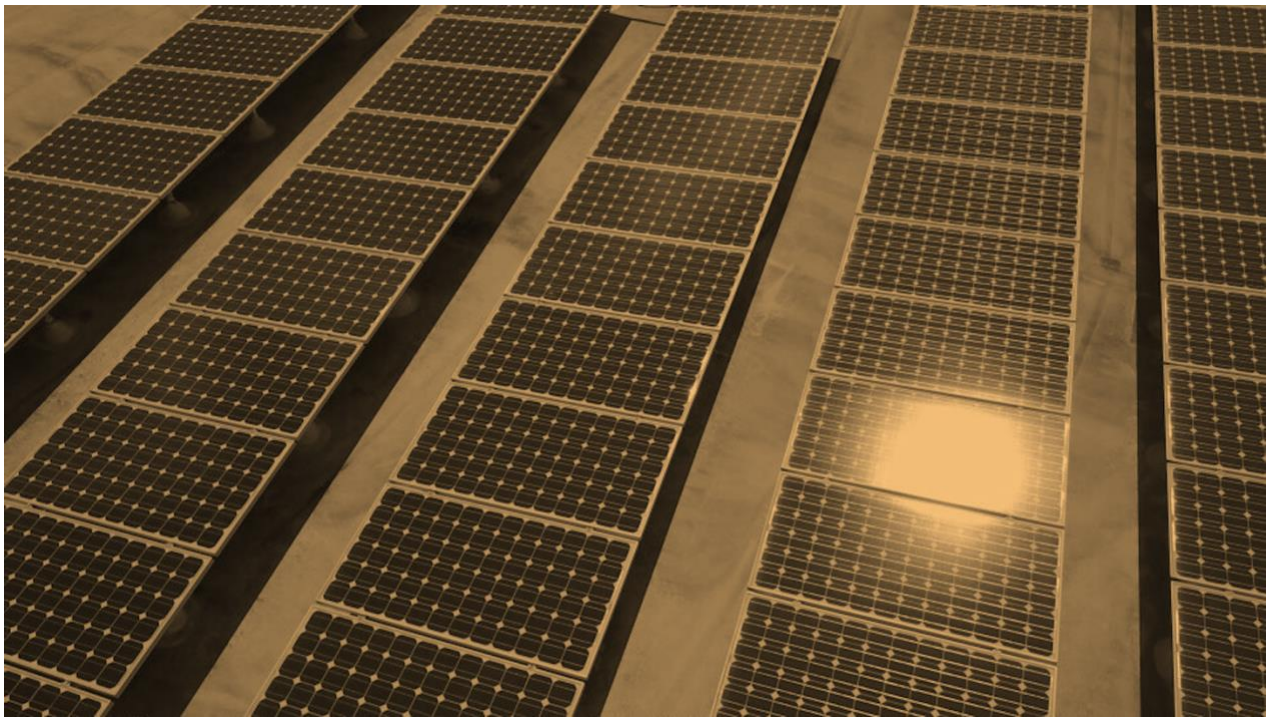
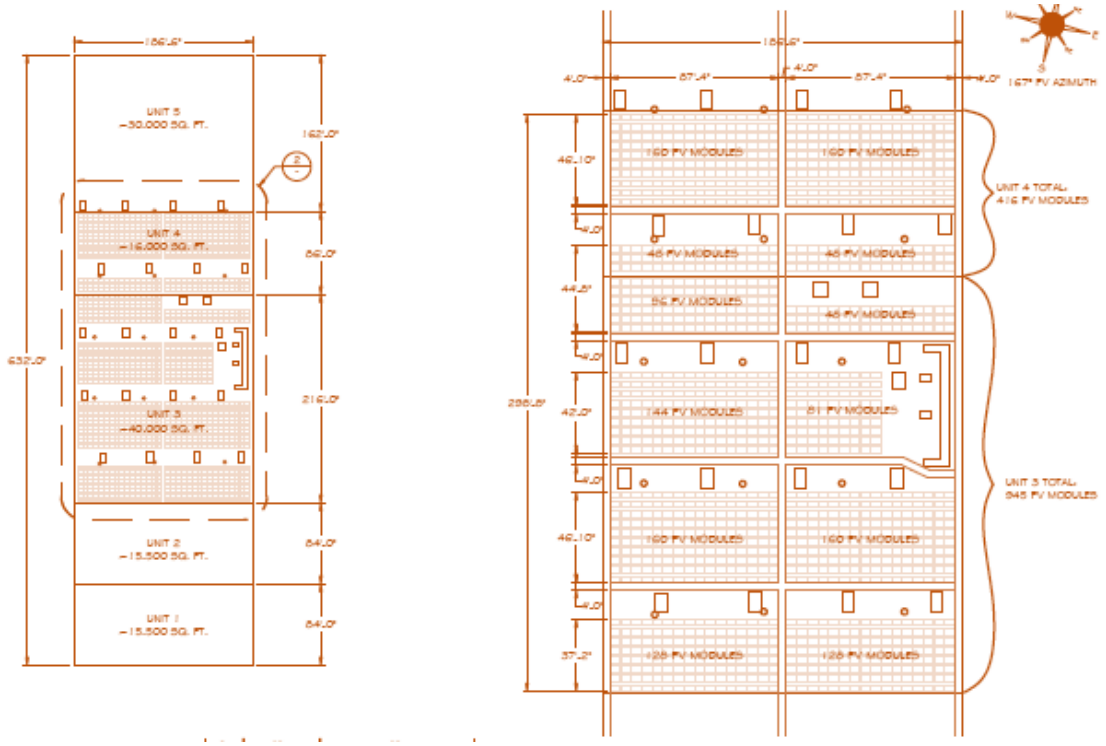


409 KW CASE STUDY: CALIFORNIA PV SOLAR PROJECT EVALUATION

A California asset owner wished to verify that a newly constructed 409 kW-DC rooftop PV system would last for its expected 25-year design lifetime. The asset owner intended to purchase the land, building and PV system from a developer. To protect their investment, the asset owner hired SepiSolar to evaluate the solar array for any deficiencies before finalizing the purchase.

A SepiSolar engineer was dispatched to the site to perform a comprehensive check of all solar system design and engineering.

SepiSolar's engineers are experienced NABCEP-certified and also have professional engineering licenses in multiple states. In addition, all SepiSolar engineers are required to work on at least one solar and energy storage project per year. This annual or bi-annual field experience enables our SepiSolar personnel to understand the front-line challenges of installation, as well as view the best practices that can often improve their design and engineering choices for future projects.



SEPISOLAR'S CHECKLIST FOR TECHNICALLY ASSESSING SOLAR PORJECTS

SepiSolar's PV technical due diligence of solar projects includes a thorough assessment with the following inspections, verifications, and performance testing:

PV Modules

- There is no cracked or broken glass on the modules
- There are no signs of delaminating or water infiltration on modules
- There are no broken, damaged or discolored module cells

PV Array

- Layout of modules is as depicted on the Array Plan. If not, drawings shall be marked up to reflect as-built conditions.
- Total number of modules in array is as shown on drawings.
- Racking components are tight and secure
- Modules are attached securely to the racking system
- Module and string homerun wiring is connected and securely fasten to racking structure
- All modules and racking system are properly grounded

DC Wiring

- DC conduits and inter-module wiring are properly installed and supported
- Wiring and conduit sizes are as depicted in the schematic diagram. If not, drawings shall be marked up to reflect as-built conditions.

DC Combiner Boxes

- Combiner boxes are properly installed and supported
- Combiner boxes are labeled per the drawings
- PV source wiring is labeled within the combiner box
- Fuses are sized as indicated on the schematic diagram
- All wiring is secure within terminals

DC Disconnect Switches

- Disconnects are properly installed and supported
- Disconnects are labeled per the drawing
- Wiring within the disconnect switch is as depicted on the schematic diagram
- All wiring is secure within terminals

AC Wiring

- AC conduits are properly installed and supported
- Wiring and conduit sizes are as depicted in the schematic diagram. If not, drawings shall be marked up to reflect as-built conditions.

PV Inverter(s)

- Inverter(s) are securely mounted to wall or floor
- There is manufacturers and NEC required clearances around the inverter
- Wiring (AC, DC and ground) within the inverter is secure and sized as depicted in the schematic diagram
- Inverter is properly labeled as indicated on the drawings

Metering and Monitoring

- Metering equipment is properly installed and supported
- Wiring with metering equipment is as depicted on drawings
- There is an active internet port for connection of the metering system

Utility Disconnect Switch

- Disconnect is properly installed and supported
- Wiring within the disconnect switch is as depicted on the schematic diagram
- All wiring is secure within terminals
- Disconnect is labeled per the drawings

PV Interconnect Breaker/Fused Switch

- Breaker/Switch is properly installed and supported
- Wiring within the breaker/switch is as depicted on the schematic diagram
- All wiring is secure within terminals
- Breaker/switch is labeled per the drawings

AC Combiner Panel (if used)

- Panel(s) are securely mounted to wall or floor
- There is required NEC clearance around panel
- Panel type and size are as depicted on drawings
- Wiring within the panel is secure and sized as depicted in the schematic diagram
- All wiring is secure within terminals
- Panel and all breakers are properly labeled as indicated on the drawings

Structural Engineering Evaluation

- Verify seismic load capacity of structure
- Calculate impact of dead and wind loads of PV array and compare against roof framing's capacity
- In areas with snow, verify snow load capacity of roof
- For ballasted systems, verify with manufacturer's documentation that ballast weight and layout is installed as per wind tunnel test reports

After the physical inspection of equipment and wiring, SepiSolar engineers conduct a series of measurement and verification tests of the system, inverter, wiring, and monitoring systems.

DC STRING WIRING TESTS

Next, SepiSolar conducts a DC wiring string test. A SepiSolar engineer opens the string fuses within combiner boxes and checks the polarity of all string circuits. When the system is operating, we measure the operating current for each string. We also measure and record the open circuit voltage for each string. With these checks, we add the following data to our checklist.

- String combiner number
- String number
- Check polarity
- Check open circuit voltage, ensuring that fuses are in the open position
- Check DC voltage, ensuring that fuses are in closed position
- Check operating current in amps

We consider that the string tests passes if the open circuit voltages are within 2% of each other and the operating currents are within 5% of each other.

DC WIRING TESTS

With all of the string combiner box fuses closed, the engineering checks and measures at each DC disconnect, the engineer checks the polarity and measures the open circuit voltage with the disconnect switch in the open position, and the open circuit voltage with disconnect in closed position.

Continuing our DC wire testing, with all of the DC disconnects closed, the engineer checks and measures the polarity and the open circuit voltage with fuses in open position, and the open circuit voltage when fuses are in the closed position.

Finally, with all of the array combiner boxes closed, for each inverter, the SepiSolar engineer checks polarity and measure once again measures the open circuit voltage when the inverter DC disconnect in open position and when it is in closed position.

AC WIRING TESTS

To assess the AC Wiring of the PV system, SepiSolar's site engineer:

- Opens the DC disconnect on the inverter(s),
- Opens the AC disconnect/breaker on the inverter(s)
- Closes the AC interconnect breaker/switch
- Measures and records the AC voltage and frequency in Hertz at the terminals of the inverter(s)

SYSTEM START UP

To ensure that the PV system is operating properly, SepiSolar shuts down the PV system and performs a complete system start up with the following procedure:

- Close the DC disconnect on the inverters
- Close the AC disconnect/breaker on the inverters
- Follow the inverter manufacturers installation manual to initiate an inverter start
- Verify successful start of the inverters
- Verify that the measured values match the displayed values on the inverter (if inverter equipped with display).
- Record total power output.

VERIFICATION OF UTILITY INTERCONNECT REQUIREMENTS

SepiSolar engineers will also verify and confirm that the system is complying with the utility's interconnection requirements.

We first verify that the inverter is operating and generating power. We then open the utility disconnect switch to confirm that the inverter immediately stops generating power.

Second, after verifying the inverter is shut down and utility disconnect switch open, we close the utility disconnect switch and confirm that the inverter starts up automatically within 5 minutes.

SYSTEM PERFORMANCE TESTING

To assess the solar system's performance, SepiSolar measures or calculates:

- Array power (in DC and STC)
- Irradiance (Watts/square meter)
- Mismatch and dust factor
- Array temperature (in Celsius, measured on back of module)
- Wiring efficiency factor
- Inverter efficiency
- Inverter output power

When operating properly, the system's output should be within 5% of calculated values.

SYSTEM METERING & MONITORING

Many system owners can assume that metering and monitoring systems are accurate, but these systems may also fail.

To check that monitoring systems are operating as expected, SepiSolar engineers first verify that monitoring system and its host are active and receiving data. Next, we conduct our field measurements, which include:

- L1 to Neutral
- L2 to Neutral
- L3 to Neutral
- L1 to L2
- L2 to L3
- L3 to L1
- Frequency
- L1 Current
- L2 Current
- L3 Current
- DC Voltage
- DC Current
- Total Power Output

We compare and record the measured field values to the monitoring systems values. A monitoring system is confirmed to be working properly when the measured values and the monitoring system's values are within 5% of each other.

409 KW CASE STUDY RESULTS

After performing the above checklist, system measurements, and verification procedures, SepiSolar discovered four minor deficiencies in our client's 409 kW-DC PV system.

The following pages describe these four issues, which were wiring and code related.

Issue #1

DC wiring is making contact with the roof surface and sharp edges of nearby equipment

NEC 110.3(B) states: “Installation and Use. Listed or labeled equipment shall be installed and used in accordance with any instructions included in the listing or labeling.”

Our recommendation:

SepiSolar engineers suggested that the DC conductors throughout the PV system be protected from making direct contact with the roof surface or sharp edges of strut and the like, to prevent abrasion and potential future faults. This is true throughout the entire PV system. In addition, we recommend that the wiring be protected from direct sunlight, in lieu of its UV-resistant rating.

Issue #2

Unapproved means for color coding DC wiring

NEC 210.5(C)(1)(a) states, “Means of Identification. The means of identification shall be permitted to be by separate color coding, marking tape, tagging, or other approved means.”

The image appears to show red spray paint used to color-code the DC wiring.

Our recommendation:

Since spray paint is not considered an approved means to identify conductors, we suggest using red electrical tape with 3 continuous stripes along the conductor at 24-inch intervals.

Issue #3

Use of RHW-2 instead of PV Wire for an ungrounded system

NEC 690.35(D) states, "Conductors. The PV source conductors shall consist of the following:

(1) Metallic or nonmetallic jacketed multiconductor cables
(2) Conductors installed in raceways
(3) Conductors listed and identified as PV wire installed as exposed, single conductors, or
(4) Conductors that are direct-buried and identified for direct-burial use"

Our recommendation:

Since the installed single conductor wires are not listed as PV Wire, SepiSolar recommended that all exposed, single conductors be replaced with PV wire.

Issue #4

Wire ties not considered an approved means to attach/affix equipment

NEC 110.3(B) states, "Installation and Use. Listed or labeled equipment shall be installed and used in accordance with any instructions included in the listing or labeling."

The temperature sensor is being held in place only by wire ties, which is not considered an approved means to attach equipment.

Our recommendation:

SepiSolar suggested that the module temperature sensor be secured in place by an approved means in order to withstand the 25-year design life of the system.

IN SUMMARY

Solar asset owners and solar asset purchasers require third party engineering firms like SepiSolar to perform due diligence and performance testing to independently inspect and verify newly built and as-built solar PV systems.

SepiSolar can perform a comprehensive checklist of system engineering checks and verifications to ensure that stakeholders are receiving an accurate assessment of their solar PV and energy storage assets, as well as issues that require repair or need to be corrected to meet local, national electrical standards and permitting requirements.

For questions or comments about the content of this case study, please contact:
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