

**SECTION 48 1400
PHOTOVOLTAIC SYSTEM**

PART 1 - GENERAL

1.01 SUMMARY

- A. This is a design-bid-build project and includes the construction and commissioning of complete Photovoltaic Systems (PV), including all AC, DC, monitoring, metering and balance of system components. The installation shall conform to all requirements as defined by the applicable codes, laws, rules, regulations and standards as specified in the Contract.
- B. This section describes requirements for the solar photovoltaic (PV) system, including:
 - 1. PV modules
 - 2. Optimizers/Rapid Shutdown
 - 3. Solar Inverters
 - 4. Metering & Data Acquisition System
 - 5. Balance of System for a complete PV system.
- C. "Owner" shall refer to owner of the site where project will be located, regardless of system ownership, and include any representative of the site owner, such as consultants or inspectors. "Contract" refers to the construction contract and any associated requirements outlined in the request for proposals (RFP). "Contractor" refers to the entity performing the work.

RELATED DOCUMENTS

- D. Contract and any documents.
- E. Other relevant Owner Specifications
- F. Where this specification and other specifications or contract documents are in conflict, the more stringent shall apply. Contractor shall identify conflicts and confirm recommended equipment or procedures with the Owner.

1.02 DEFINITIONS

- A. AC: Alternating Current.
- B. AHJ: Authority Having Jurisdiction.
- C. BOS: Balance of System
- D. CEC: California Electrical Code -OR- California Energy Commission

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- E. COD: Commercial Operation Date
- F. CPUC: California Public Utilities Commission.
- G. DAS: Data Acquisition System.
- H. DC: Direct Current.
- I. MPPT: Maximum power point tracking.
- J. MW: Megawatt
- K. NEC: National Electrical Code.
- L. NEM: Net Energy Meter.
- M. NEM-A: Net Energy Metering Aggregation
- N. NEMA: National Electrical Manufacturers Association
- O. PTC: PVUSA Test Condition, commonly regarded as "real-world" measure of PV output.
- P. PTO: Permission to Operate with the electrical utility.
- Q. PV: Photovoltaic.
- R. STC: Standard Test Conditions defined in IEC 61215.
- S. UL: Underwriters Laboratories.

1.03 CODES & REFERENCES

- A. The installation shall conform to all requirements as defined by the applicable codes, laws, rules, regulations and standards of applicable code enforcing authorities (Latest Edition unless otherwise noted). The following are key standards that shall be followed. The Contractor shall ensure all applicable codes are followed:
 1. ASTM International (ASTM) (www.astm.org), including:
 - a. E3010, Standard Practice for Installation, Commissioning, Operation, and Maintenance Process (ICOMP) of Photovoltaic Arrays
 2. American National Standards Institute (ANSI)
 3. California Building Code (CBC), with State of California Amendments
 4. California Energy Commission Title 24 Building Energy Efficiency Requirements
 5. California Department of Forestry and Fire Protection, Office of the State Fire Marshal – Solar Photovoltaic Installation Guidelines
 6. California Public Utilities Commission (CPUC), Including Title 21
 7. Institute of Electrical and Electronics Engineers (IEEE)
 8. International Electrotechnical Commission (IEC), including:
 - a. 62446-1 Photovoltaic (PV) systems – Requirements for testing, documentation and maintenance. Part 1: Grid connected systems – Documentation, commissioning tests and inspection
 9. International Electrical Testing Association (NETA)
 10. Local Fire Permit Requirements
 11. National Electrical Manufacturers Association (NEMA)
 12. National Fire Protection Association (NFPA), National & California Electrical Code
 13. Underwriters Laboratory (UL), including:

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- a. UL 2703 – Standard for Mounting Systems, Mounting Devices, Clamping/Retention Devices, and Ground Lugs for use with Flat-Plate Photovoltaic Modules.
- 14. Utility company standards and requirements
- 15. Division of the State Architect (DSA), including:
 - a. DSA IR-16-8 (most recent) Guidelines
 - b. DSA PL-07-02 (most recent) Guidelines
- 16. Owner Specifications and Requirements
- 17. All other applicable Codes and Ordinances

1.04 WORK INCLUDED

- A. The work includes the materials, labor, equipment, installation, testing, services, and incidentals necessary to install complete Photovoltaic (PV) Systems in conformity with the Contract, applicable codes and professionally recognized standards.
- B. Include all items and all work reasonable required to complete the System in accordance with the Agreement. If the Contractor is in doubt as to the intent of any portion of these specifications, or necessary information is omitted, the Contractor shall notify the Owner in writing for clarifications or corrections to be provided by addendum.
- C. Submittal documents, cut sheets, shop drawings, and technical specifications shall be submitted, reviewed and accepted by the Owner per the guidelines specified in the Contract documents.
- D. PV systems shall consist of arrays of framed photovoltaic modules, mounting hardware, terminal boxes, combiner boxes, quick-connect electrical connectors, DC wiring, DC disconnects, utility interactive inverters, AC disconnects, AC feeders, AC circuit breakers, AC panel boards / switchgear, complete data acquisition and monitoring systems, rapid shutdown devices where required, and any other equipment described or inferable from the Contract Documents.
- E. Metering, monitoring system, DAS, weather stations, and cellular modem equipment, including subscriptions for first five years.
- F. Utility grid interconnection, including all interconnection application coordination during construction, commissioning and startup. Work shall include, review of any previous interconnect applications, bus-tap design, utility company coordination, revisions to interconnect applications as-needed, inspections, permits and their costs, and final approval for the complete interconnection and PTO of the PV systems with the utility company grid. See Section 3.06 for further detail.
- G. The Contractor shall provide for the disconnection, disposition, and proper disposal of all existing equipment to be demolished and/or replaced.

1.05 CONDITIONS AT SITE

- A. Contractor is responsible for familiarizing themselves with all discernible site conditions. No extra payment will be allowed for work required because of these conditions, whether specifically mentioned or not. See Section 01 10 00 Summary of Work for further detail.
- B. Lines of other services and other site improvements that are damaged as a result of this work shall promptly be repaired at no expense to the Owner and to the complete satisfaction of the Owner.

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1.06 SUBMITTALS

A. ACTION SUBMITTALS

1. PRODUCT DATA: For each type of product.
 - a. Include construction details, material descriptions, dimensions of individual components and profiles, weights and finishes.
 - b. Manufacturers' datasheets, specifications, and other data required to demonstrate compliance with the specified requirements. Include rated capacities, operating characteristics, electrical characteristics, and furnished specialties and accessories.
 - c. Complete material list of all items proposed to be furnished and installed under this Section, including but not limited to the following items: PV modules, Inverters, conductors, PV connectors, ground lugs (where not provided by PV mounting rack manufacturer), cable clips, cable ties, wire management products, PV wire strain relief, PV wire gland fittings, PV wire abrasion protection, conduit and fittings, conduit supports, cable tray and fittings, pull boxes, structural fasteners and anchors, monitoring systems, DC string fuses, rapid shutdown devices, and all other BOS to provide a complete PV system.
 - d. Manufacturers' recommended installation procedures which, when approved by the Owner, shall become the basis for inspecting and accepting or rejecting actual installation procedures used on the work.
2. SHOP DRAWINGS shall include:
 - a. Cable tray plan and details, if proposed for array wiring.
 - b. Proposed method to enclose PV wire at transitions.
 - c. All Shop Drawings shall include:
 - i) Plans, elevations, sections, and mounting details.
 - ii) Details of equipment assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
 - iii) Detail fabrication and assembly.
3. Commissioning and Performance Testing Protocol

B. INFORMATIONAL SUBMITTALS

1. Field quality-control reports.
2. Warranty: Manufacturer's special materials and workmanship warranty and minimum power output warranty.
3. Hazardous Materials Documentation: Environmental impact of system equipment containing hazardous materials shall be provided from the Manufacturer. Documentation shall include disposal instructions for equipment at the end of its useful life.

C. CLOSEOUT SUBMITTALS

1. See Section 01 33 00 and Section 3 for closeout submittal requirements.
2. At a minimum, closeout submittals shall include the following documentation, provided in electronic format:
 - a. As-built drawings in PDF format

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- b. Commissioning documentation
- c. Performance testing documentation
- d. Closeout documentation library

3. AS-BUILTS

- a. Contractor shall maintain "as-built" records at all times, showing the exact location of the PV system, including concealed conduits and feeders installed under this contract. As-builts shall also document module stringing.
- b. Upon completion of work and before acceptance can be considered, the Contractor must forward to the Owner, a corrected set of as-built plans, highlighting any updates, to show the mounting system work as installed in both PDF and CAD format.
- c. Comply with additional "As-built" requirements in other sections of the Specifications.

1.07 INSTALLER QUALIFICATIONS

- A. Contractor shall have and maintain a current California Class A or Class B and C-10 license for the duration of the Contract.
- B. Contractor shall be familiar with the equipment to be installed and have the necessary training to install in the equipment. For equipment where a manufacturer certifies installers, installer shall possess certification from the manufacturer's products being installed.

1.08 MATERIALS, DELIVERY, STORAGE, AND HANDLING

- A. All equipment shall be listed to Underwriters' Laboratories (UL) standards as applicable.
- B. All materials shall be delivered new, undamaged and without defects.
- C. All equipment and panels shall be handled with care so as not to damage the delivered products. All equipment shall be installed in new and neat condition. Any damage to Structural Steel shall have all rust removed and be recoated per structural steel specifications.
- D. Appropriate protective clothing shall be worn when handling the equipment. Such clothing shall include eye and ear protection, hard hats and steel-toe boots when lifting materials to overhead, and insulated gloves when working on an active system.
- E. Where PV systems will be installed on a roof or overhead, all materials stored on the roof shall be distributed so as not to overload the roof at any point. All materials stored on roof shall follow the guidelines of the roofing system manufacturer including protection boards, pallets and/or mats to prevent damage to the roof system and insulation assemblies. All roof top construction, construction related traffic and staging areas shall have protection boards in place to prevent damage to the roofing system and insulation assemblies.

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1.09 WARRANTY

- A. MANUFACTURER'S WARRANTY
 - 1. Manufacturer agrees to repair or replace components that fail in materials or workmanship within specified warranty period.
 - 2. Manufacturer Minimum Warranty Periods shall be:

- a. Modules: 25-years module power output guaranteed at minimum 80% at 25-years.
 - b. Inverters: 10-years.
 - c. Monitoring & DAS System: 5-years
 - d. Weather Station: 5-years
3. Contractor shall ensure that all components are installed per the Manufacturer’s requirements such that warranties are maintained. Contractor shall notify Owner of any issues with the design or installation that could impact equipment warranties and seek Owner approval prior to installation.
 4. Contractor shall provide a warranty, inclusive of troubleshooting and repair of all work, per Section 01 10 00, Summary of Work requirements and utility interconnect rules.

PART 2 - PRODUCTS

2.01 GENERAL

- A. Acceptable system manufacturers/vendors shall meet the minimum criteria and warranties described in this specification and as required in other sections of the Contract and Bridging Documents.
- B. Manufacturers shall provide their latest line of equipment, meeting all current industry standards, utility requirements and criteria set forth in the Contract. The Owner seeks equipment from proven, industry leading manufacturers in solid financial standing, producing “tier-one” financeable equipment.
- C. Contractor proprietary products shall have an ICC report or a testing report stamped and signed by a licensed California engineer.
- D. All equipment shall be listed to Underwriters’ Laboratories (UL) standards as applicable and be listed for the I.
- E. All equipment costs shall include all known and future duties, tariffs, export tariffs, customs, demurrage, and shipping costs.
- F. All major components of the systems and the installation procedures shall meet CEC requirements, including Articles 690 and 705.
- G. No substitution for contracted equipment shall be made without the written consent of Owner.

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2.02 PV SYSTEM EQUIPMENT

- A. PV MODULES shall meet the following:
 1. Module manufacturer that has produced no less than 250-MW of modules in the prior year.
 2. Modules are from a field-tested product line that has been commercially available for no-less than three years.
 3. Module manufacturer shall provide a 25-year warranty on the solar modules with at least 80 percent power output guaranteed at 25 years. The solar module manufacturer shall confirm that the warranty applies on an “as installed basis,” i.e.,

the warranty will confirm the panels were installed according to its requirements and specifications for installation.

4. Have a minimum 25-year design life, designed for normal, unattended operation.
5. UL 1703 listed.
6. UL listed for the specified voltage.
7. Meet IEC 61215 (crystalline silicon PV modules).
8. Meet California SB1 Guidelines for Eligibility.

B. RAPID SHUTDOWN DEVICES

1. Rapid shutdown devices shall be included wherever required for compliance with CEC 690.12 requirements (Rapid Shutdown of PV Systems on Buildings) or to meet other code requirements.
2. Devices shall at a minimum meet the following requirements:
 - a. Meet CEC 690.12 requirements (Rapid Shutdown of PV Systems on Buildings).
 - b. SunSpec Rapid Shutdown Certified.
 - c. Be certified for use with the specified module and inverter.
 - d. Wherever commercially available, device should be pre-installed by the module manufacturer.

C. INVERTERS shall meet the following:

1. String-type inverters.
2. Manufacturer produced no less than 250-MW of inverters in the prior fiscal year.
3. Field-tested product line that has been commercially available for no less than 2 fiscal years.
4. Comply with the following:
 - a. UL 1741 listed, inclusive of UL 1741-SA requirements.
 - b. IEEE 1547, including testing to IEEE 1547.1 and IEEE C62.45.
 - c. IEEE C62.41.2 and CSA107.1-01.1.
 - d. California Rule 21, CEC approved and utility line interactive type.
5. SunSpec Rapid Shutdown Certified for installations requiring rapid shutdown.
6. For rooftop applications and any other application where Rapid Shutdown is required, the inverter and optimizer or rapid shutdown device shall be certified by the manufacturer to meet the current CEC Section 690 requirements.
7. Incorporate disconnect switch for main DC power disconnect in compliance with applicable codes and utility requirements.
8. Meet the following requirements:
 - a. Nominal AC Voltage (Three-phase, + 10%): 208 or 480 V-AC or as specified on plans
 - b. Nominal AC Frequency (+ 0.5 Hz): 60 Hz
 - c. Line Power Factor (Above 20% rated power): >0.99
 - d. AC Current Distortion (At rated power): <5% THD
 - e. Maximum Open Circuit Voltage DC: 1,000 V-DC.

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- f. Maximum Ripple Current (% of rated current): <5%
- g. Minimum Inverter Efficiency: >96%
- h. Temperature Range Ambient: -4° F to 122° F (-20° C to 50° C)
- i. Enclosure Environmental Rating (minimum): NEMA 3R (NEMA 4X within 5 miles of a marine environment or high dust area)
- j. Relative Humidity (non-condensing): 0-95%
- k. Sound level: <85 dBa
- l. Capable of producing reactive power to operate between a power factor of 0.9 lagging to 0.9 leading (as adjusted on the inverter equipment).
- m. Protective Functions: Standard wakeup voltage, wakeup time delay, shutdown power, shutdown time delay, AC over / under voltage and time delays, AC over / under frequency and time delays, ground over current, over-temperature, AC and DC over current, DC over voltage
- n. User Display: Standard-LCD with on/off capability and physical screen cover or other means of protection from UV exposure.
- o. DC Disconnect: 1,000 V-DC load break rated (or higher where DC voltage is higher).
- p. Seismic Rating appropriate for the site and installation method.
- q. Internal combiner panel option to allow connections of sub-arrays at the Inverter without the use of additional equipment.

D. MONITORING & DATA ACQUISITION SYSTEM (DAS)

1. Contractor shall provide the following monitoring instrumentation:
 - a. PRODUCTION METER – A PV system production meter measuring the output of the solar array on a minimum 15-minute interval.
 - b. CONSUMPTION METER – A separate consumption meter shall be provided for each utility account on a minimum 15-minute reporting interval. Consumption meters shall be synced with PV meter production intervals. Consumption metering shall provide for clear disaggregation of PV production and site consumption.
 - c. WEATHER STATION – A weather station shall be provided at all sites. The station shall provide at a minimum: solar irradiation (coplanar and horizontal), ambient temperature, wind sensor and any other data relevant to weather correction of solar PV system performance.
2. A Data Acquisition and Monitoring System (DAS) shall be provided for all points of interconnect. The DAS shall include, but not be limited to, the measurement, calculation, display, and reporting of the following items:
 - a. PV production in 15-min reporting intervals.
 - b. Energy consumption in 15-min reporting intervals.
 - c. Weather data in 15-min reporting intervals
 - d. Varying levels of summary data, including daily, weekly, monthly and yearly intervals.
 - e. A minimum of 1-year of 15-min interval data shall be downloadable in a single instance.
 - f. System electrical functions (instantaneous and accumulated power output (kW and kWh), AC and DC system voltage and amperage, and peak value tracking with associated time stamps).

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- g. CO₂ emissions avoided from the generation of PV energy at the site (compared to local utility fuel mix electric carbon content). CO₂ avoidance factor shall be readily customizable for the local utility.
 - h. Capable of outputting data in the Western Renewable Energy Generation Information System (WREGIS) format sufficient for registering Renewable Energy Credits (RECs) from each system.
 - i. Lifetime logging and access to data reported by DAS, including database-level, "unprocessed" data for lifetime of system operation.
 - j. Provide access by unlimited individuals to data via the internet for each Site. Data shall be available on a real-time and daily basis to Owner/Owner's representative and must be sufficient to establish an operational baseline.
 - k. DAS shall provide access to all data through an open data exchange protocol (FTP Push or Application Program Interface (API)) to Owner and Owner's Third-Party Designee at no additional cost. This data shall, at a minimum, include PV production data, energy consumption data, inverter production data, inverter AC power data, inverter current data, inverter voltage data, weather station and/or satellite data, weather-adjusted expected production data, and alarm status readings. All data shall be available over multiple timescales, ranging from 15-min intervals to annual intervals and shall include both real-time and historic data.
3. Hard wire connections shall be used for communications with the DAS and metering systems.
 4. Contractor shall ensure all systems are properly installed, and cloud-based systems are setup and functional. Commissioning shall include checks of the monitoring/DAS systems and confirmation of proper setup/function. Contractor shall provide logins and orientation to the Owner for all monitoring and DAS systems.

2.03 BALANCE OF SYSTEM

A. CONDUITS & RACEWAYS

1. All roof and exterior mounted raceways shall be designed and installed to accommodate expansion and contraction due to heating affects, including adequate cable length and listed expansion couplings. All expansion couplings or installations shall include grounding bonding jumpers as required by code.
2. Outdoor conduit shall be rigid galvanized steel with threaded fittings. Outdoor connections to boxes shall use raintight fittings. All conduit shall meet CEC Code, and any applicable standards. All conduit shall be rated for exposed installation and a minimum design life equivalent to the solar panels. Colors to be selected and approved by the Owner.
3. Paint all visible exposed raceways and boxes to match adjacent surface finish after installation per Exterior Painting Specification 09 91 13.
4. For canopy installations, all conduits and stub-ups under canopies shall be encased within concrete caissons or piers. Where conduits or stub-ups are not at canopy base, they shall be protected from vehicle strikes with appropriately sized bollards if protection is required by code or the electrical engineer.
5. All interior conduit to be EMT with steel compression fittings (no cast fittings).

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6. Raceway system shall be designed/installed in a manner that prevents water from draining into electrical equipment.
- B. DC CIRCUITS AND FEEDERS shall be:
1. 2-wire + ground and stranded.
 2. Minimum No. 10 AWG for DC string circuits.
 3. Type PV marked minimum 1000V and sunlight resistant.
 4. Installed in raceways or cable tray, except where supported and protected by PV modules.
 5. Sized to CEC table 310.15(B)(16) (90-degree column). Minimum ampacity shall be 156% of the rated short circuit current available to be carried on the specific conductor. Conduit fill to 40% max. Include temperature derating as required for the ambient temperatures and roof conditions per CEC, and conduit fill derating as required. Provide equipment grounding conductor in each conduit.
- C. AC CONDUCTORS shall be:
1. Sized per applicable sections of CEC Articles 310, 690 and 705. Conduit fill to 40% max. Include temperature derating as required for the ambient temperatures and roof conditions per CEC. Provide equipment grounding conductor in each conduit.
 2. 4-wire + ground, as required by inverter manufacturer's installation manual. All grounding per CEC 690, Part V.
 3. Installed in raceways.
 4. Type XHHW-2 for wet and dry locations.
- D. DC string fuses shall be 1000V-DC rated per design and UL listed for PV application. The amp rating shall be equal to the series fuse rating of the PV module. If not provided with inverter, Contractor shall provide DC string fuses. Minimum of one spare fuse shall be supplied for each inverter.

2.04 MISCELLANEOUS REQUIREMENTS

- A. The modules shall be interconnected using cable assemblies. The pigtails shall be quick-connect electrical wiring connections rated for the application (90-degree rated). DC string connectors for homerun wires and jumpers provide by the Contractor must match the make and model of the connectors supplied with the PV module, or must be UL listed as compatible with the connectors supplied with the PV module.
- B. The Contractor shall ensure adequate clearance and equipment space within the allotted areas and existing building and site conditions. All equipment and sizes / clearances shall be coordinated with the Owner prior to rough-in.
- C. All exterior equipment to be sunlight and UV resistant as well as rated for elevated temperatures at which they are expected to operate (on roofs in hot sunlight).
- D. No dissimilar metals are allowed to contact each other (use deox, joint compound, plastic or rubber washers) with the exception of anodized aluminum module frames in contact with galvanized steel rack framing. Best practices shall be used to avoid corrosion.
- E. No aluminum in contact with concrete or masonry materials.

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- F. Bolted connections shall be non-corrosive and include locking devices designed to prevent twisting over the design life of the PV system.
- G. Combiner boxes (where used) shall be NEMA 3R rated (minimum, NEMA 4X shall be used within 5 miles of a marine environment) and shall include fuses for string inputs and a bus bar to combine the strings into sub-arrays, for input into the Inverter system. Minimum combiner box output bus ampacity shall be 156% of the rated short circuit current available to be carried on the bus (the sum from all strings to the bus).
- H. The PV system shall be designed to automatically drop offline when normal utility power is lost to avoid unintentional islanding effects as required by the local utility. Exceptions may be made by Owner where PV system is part of an emergency power/battery backup allowed by Utility and AHJ.
- I. All electrical system equipment shall be properly rated to withstand and interrupt (in the case of over current protection devices) 110% of the available fault current at the point of use.
- J. All required overcurrent protection and electrical bussing sizes per CEC 690.
- K. Means of system grounding to be approved by professional Electrical Engineer of record and GFCI protection shall be in accordance with latest CEC requirements.
- L. Arc-fault protection where applicable per CEC 690.11.
- M. For PV system supply side interconnection, the Contractor shall inspect the existing main service switchgear to confirm suitability of the switchgear supply side bus for interconnection of the PV system. Where required by the AHJ, any modification of the existing switchgear necessary to construct the supply side connection shall be approved by the switchgear manufacturer or a Nationally Recognized Testing Laboratory. Where a NRTL approves modification of the switchgear, a field labeling report shall be provided to the Owner. The Contractor is responsible for obtaining switchgear manufacturer approval of any modification required to accommodate the supply side connection, or NRTL approval and report.
- N. Outdoor grounding connections between dissimilar metals (such as aluminum lugs and copper wire) will be protected against galvanic corrosion by the application of outdoor-rated deox or conductive joint compound between the interfacing metal surfaces.

PART 3 - EXECUTION

3.01 EXAMINATION

- A. Examine substrate areas and conditions, with Installer present, for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.
- B. Do not begin installation until mounting surfaces have been properly prepared.
- C. If preparation of mounting surfaces is the responsibility of another installer, notify Owner of unsatisfactory preparation before proceeding.
- D. Examine modules, inverters, DAS and all other BOS equipment before installation. Reject components that are damaged or have been stored or handled improperly.

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- E. Examine roofs, supports, and supporting structures for suitable conditions where PV system will be installed.
- F. Proceed with installation only after unsatisfactory conditions have been corrected.

3.02 INSTALLATION

A. INSTALLATION STANDARDS

1. System Installation shall conform to the equipment manufacturers Installation Manual(s) and requirements or guidelines.
2. All Local, State, and CEC codes shall be observed, including all industry standards related to the installation, operation, and maintenance of photovoltaic power systems.
3. Comply with NECA 1, Standard for Good Workmanship in Electrical Construction.

- B. Coordinate layout and installation of PV modules with mounting assembly and other construction. Install PV modules, inverters, rapid shutdown devices, DAS and other PV system components in locations indicated on plans.
- C. Support PV panel assemblies independent of supports for other elements such as roof and support assemblies, enclosures, vents, pipes, and conduits. Support assembly to prevent twisting from eccentric loading.
- D. Install weather seal fittings and flanges where PV panel assemblies penetrate exterior elements such as walls or roofs. Seal around openings to make weathertight. See related specifications and drawing notes for waterproofing requirements.
- E. Seismic Restraints: Seismic-restraint devices shall be employed per the design documents and code requirements.
- F. Wiring Method: Install all AC cables in raceways. PV wire may be routed in free air beneath solar PV modules and where not exposed to physical damage.
- G. Wiring within Enclosures: Bundle, lace, and train conductors to terminal points with no excess and without exceeding manufacturer's limitations on bending radii. Install lacing bars and distribution spools.
- H. System installation shall conform to the equipment manufacturers' installation manuals and all related requirements and guidelines.

3.03 CONNECTIONS

- A. Coordinate PV panel cabling to equipment enclosures to ensure proper connections.
- B. Tighten electrical connectors and terminals according to manufacturer's published torque-tightening values. If manufacturer's torque values are not indicated, use those specified in UL 486A-486B.
- C. Make splices, terminations, and taps that are compatible with conductor material and that possess equal or better mechanical strength and insulation ratings than un-spliced conductors.
- D. PV wire splices shall be made with listed PV connectors of the same make and model only.

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3.04 WIRE MANAGEMENT

- A. All wiring methods must meet or exceed current industry standards for wire management, strain relief and fastening.
- B. All DC string wire management shall use stainless steel or galvanized steel cable clips, Heyco or similar. UV rated cable ties shall be used minimally and only in locations where the use of cable clips is impossible.
- C. Wiring shall not be routed over sharp edges of structural members, equipment or modules.
- D. Wiring shall be routed under the modules of the array wherever possible to avoid direct exposure to the sun or elements.
- E. Wiring shall be secured under the array so as to prevent excessive slack resulting in wire motion, and to minimize visibility of inter-module and home run wiring to the public.
- F. Excess slack in the wire shall be secured such that it is in the module channel or secured to the junction box of the module. Factory-installed wire leads for modules can be wrapped around the junction box of the module.
- G. Where exposed, wires, cables and conductors shall be managed in a neat and orderly manner. Where exposed to environmental conditions (e.g., sunlight, rain, wind, etc.) and visible from below, wires shall be fastened in a uniform and discrete fashion.
- H. All conductors and conduits between separate arrays shall be routed underground. Wiring shall be routed down columns, encased in piers/caissons, routed underground between arrays or carports, and up the nearest column on the adjacent array. Under no circumstance shall circuits, conduits, or chaseways be mounted overhead between separate structures, including seismic gaps.
- I. Strain relief and drip loops shall be utilized at all entrances to and from conduit bodies, junction boxes, weather heads, switchgear, inverters and panelboards etc. Conductors shall be strapped with strain relief as not to stress panel leads, home runs or mechanically crimped connections within the array. Sufficient slack shall be provided at both ends of cables to allow service and re-termination, and to prevent thermal expansion and contraction from stressing connections.
- J. Wire in switchboards, panelboards, meter cabinets, pull boxes, and other cabinets shall be neatly grouped and tied in bundles with nylon ties rated for the temperature rating of the electrical equipment at 10-inch intervals. In switchboards, panels and terminal blocks, wires shall be fanned out to terminals and trained for straight entry into the terminals. At no point shall nylon ties be used on bussing or bussing used in any manner to support other materials including but not limited to circuit conductors.
- K. Maintain the conductor required bending radius per NEC and manufacturer specifications.
- L. Wires shall not be installed until debris and moisture is removed from conduits, boxes, and cabinets. Wires stored at site shall be protected from physical damage until they are installed and walls are completed.
- M. Wire-pulling compounds furnished as lubricants for installation of conductors in raceways shall be compounds approved and listed by UL, NRTL, or equal. Oil, grease,

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graphite, or similar substances are not permitted. When pulling conductors, do not exceed manufacturer's recommended values.

N. CONDUCTOR COLOR CODES

1. AC Circuits (<600V): Conductors must be color-coded by phase and voltage as required by NEC, the AHJ, and the utility.
2. DC Circuits, grounded

<u>Conductor Color</u>	
Positive	Red
Negative	White
3. DC Circuits, ungrounded

<u>Conductor Color</u>	
Positive	Red
Negative	Black
4. For phase and neutral conductors 6 gauge or larger, permanent thermoplastic-colored tape may be furnished to mark conductor end instead of coded insulation. Tape shall cover not less than 2 inches of conductor insulation within enclosure.

O. TAPE AND SPLICE KITS

1. Wire splice kits shall be UL listed for their manner of use, such as direct burial or wet operation. Splices, joints, and connectors joining conductors in dry and wet locations shall be covered with listed insulation approved by the manufacturer for use with the splice, or as contained in the listed splice kit. Free ends of conductors connected to energized sources shall be taped.
2. Thermoplastic insulating material approved by UL, NRTL, or equal for installation as sole insulation of splices shall be furnished and shall be installed according to manufacturer's printed specifications. Standard electrical tape shall not be the sole insulation material for splices unless explicitly listed for use in the application and meeting the temperature rating of the insulation requirements for the splicing connection.

P. TERMINATIONS

1. Terminations of conductors shall be performed to the requirements and recommendations listed within the manufacturer manuals of the termination hardware and equipment where the termination shall occur.
2. Conductors shall be terminated with minimal exposure of the bare conductor.
3. Conductors cannot exceed the size and quantity restrictions of the lug. Contractor to verify equipment lugs supplied will accept the size and quantity of conductors shown in the project drawings.
4. Full engagement of the conductor within the lug must be maintained.
5. Provide necessary coating of anti-oxidation coating on all exposed conductor ends entering the lug.
6. Where mechanical connectors are used, torque all set-screws to manufacturer specifications with a calibrated torque wrench and indicate with torque marks. Torquing electrical connectors "hand tight" is not allowed.

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7. Where compression connectors are used, they must be installed with compression tools and dies approved by the manufacturer for use with the connector.
8. Ensure the final portion of the conductor before entering the termination is not part of a conductor bend (straight on entry).
9. Termination fittings, connectors, and lugs must be rated and listed for the conductor metal type connected.

Q. GROUNDING

1. Washer-type PV module grounding devices shall be listed for grounding PV modules to galvanized steel substrate and shall be installed according the manufacturer's installation manual with appropriate bolt size and clearance hole size.
2. All PV modules shall be bonded to each other and to the racking structure with listed PV module grounding devices and equipment grounding conductors. Where the PV modules are listed for use with a UL 2703 listed PV mounting rack, the rack shall meet this requirement and manufacturer requirements.
3. Where PV modules and steel purlins are grounded and bonded, contact between dissimilar metals such as copper and galvanized steel shall be avoided. Where contact cannot be avoided, outdoor-rated deox or conductive joint compound shall be applied between the interfacing metal surfaces.
4. Outdoor grounding connections between dissimilar metals (such as aluminum lugs and copper wire) will be protected against galvanic corrosion by the application of outdoor-rated deox or conductive joint compound between the interfacing metal surfaces.

5. GROUNDING ON ROOFTOP RACKING SYSTEMS

- a. Bond per CEC requirements with a separate grounding conductor as indicated on the contract drawings.

6. GROUNDING ON CANOPIES

- a. Contractor shall submit proposed method for mounting and grounding PV modules to the canopy structure per CEC and the contract drawing requirements. The proposed method shall meet AHJ requirements and utilize either of the following:
 - i) UL 2703 listed module mounting and grounding clamps and devices.
 - ii) UL 2703 listed pathways that are listed for the application and follow manufacturer requirements.
 - iii) Direct bolting of the module to the canopy steel structural purlins and UL listed PV module grounding devices.
- b. If PV modules are mounted to the canopy structure with module mounting clamps, the clamps must be approved for this purpose by their manufacturer as part of a UL 2703 listed assembly. Clamps shall be listed for PV module grounding to galvanized steel substrate, and their installation shall comply with the clamp installation manual and the PV module installation manual.
- c. If PV modules are direct bolted to the canopy steel structural purlins, mounting bolt size and specification must be written and detailed in the canopy structural drawings. Mounting bolt size must comply with the PV module installation manual, and be compatible with the module mounting hole diameter.

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- d. All PV modules shall be bonded to each other and to the canopy galvanized steel structural purlins with listed PV module grounding devices and equipment grounding conductors. The canopy galvanized steel structural purlins shall be bonded to the structural beams, unless a welded structural connection exists between the purlins and beams. An equipment grounding conductor shall ground the PV array to the PV inverter ground bar, and a grounding electrode conductor shall ground the PV inverter to the canopy grounding electrode.
- e. Where PV modules and steel purlins are grounded and bonded, contact between dissimilar metals such as copper and galvanized steel shall be avoided. Where contact cannot be avoided, outdoor-rated deox or conductive joint compound shall be applied between the interfacing metal surfaces.

3.05 IDENTIFICATION

- A. Identify equipment, boxes, raceways with placards and labels as indicated on plans. All placards and labels shall comply with CEC articles 690 and 705 and Section 26 05 53 "Identification for Electrical Systems".
- B. Placards: Unless noted otherwise on plans or required by code, all placards shall be machine generated phenolic type with red background and white lettering, affixed to equipment with stainless steel screws or with permanent adhesive where set screws are not feasible. Minimum lettering size shall be 1/4" high unless indicated otherwise.
- C. Labels: Unless noted otherwise on plans, all labels shall be machine generated peel and stick UV-resistant vinyl labels rated for outdoor conditions with red background and white lettering, affixed to raceways and other components as indicated on plans. Minimum lettering size shall be 1/4" high unless indicated otherwise.
- D. Contractor shall provide all placards as required by code, the utility and the design. The following specific placards shall be provided, in addition to any others required by code, utility or the design:
 - 1. All placards shall be machine generated phenolic type with red background and white lettering, affixed to equipment with stainless steel screws or with permanent adhesive where set screws are not feasible. Minimum lettering size to be 1/4" unless otherwise noted or required for legibility.
 - 2. Provide a placard clearly visible at each main service panel to identify both sources of power, with the following wording in 1/4" high lettering per CEC 690.64(B)(4):
"Warning - This Service Is Fed by Two Sources Of Power – The Utility Service Main Disconnect And The PV System Main Disconnect – Both Services Must Be Disconnected To Remove Power From The Switchboard".
 - 3. Provide a placard on each PV system input circuit breaker (where used) at the main panel with the following wording in 1/4" high lettering per CEC 690.64(B)(7):
"Warning – Inverter Output Connection – Do Not Relocate This Overcurrent Device".
 - 4. Provide a placard on all disconnects with the following wording in 1/4" high lettering per CEC 690.17: "Warning - Electric Shock Hazard - Do Not Touch Terminals - Terminals On Both The Line and Load Sides May Be Energized In The Open Position".
 - 5. Provide a placard on the Main PV System Disconnect (adjacent to each main service panel) with the following information in 1/4" high lettering per CEC 690.53:
"Photovoltaic Power Source Disconnect - Operating Current: X Amps; Operating

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voltage: XX VAC; Maximum System Voltage: XX VAC; Short-Circuit Current: XXX Amps”, where X is the operating current, XX is the system voltage, and XXX is the maximum short circuit current contribution of the generating facility at the point of interconnection with the utility system.

6. Provide a placard on the respective Main Switchboard to identify the two sources of power feeding the equipment. Include the following information in 1/4” High lettering per CEC 690.54: “Caution - Possible Backfeed From Photovoltaic Power System – X VAC, XX Amps”, where X is the system voltage and XX is the maximum AC amperes of the installed system.
7. Provide a placard on each PV System Inverter with the following information in 1/4” high lettering: “Photovoltaic Power Source Inverter Rating - Operating Current: XX Amps; Operating voltage: XXX VDC; Maximum System Voltage: 1,000 VDC; Short-Circuit Current: XXXX Amps”, where XX is the maximum DC amperes of the installed system, XXX is the operating voltage DC, and XXXX is the short circuit current that the Inverter can provide (from all strings in parallel).
8. Provide utility-required System Directory placard and utility safety switch Identification placard as required by local utility company, to identify all system components.

E. CONDUCTOR IDENTIFICATION

1. All conductors, including DC homerun circuits, shall be labeled at each point the conduit run is broken by a cabinet, box, gutter, etc. Where terminal ends are available, identification shall be by means of heat shrink wire markers.
2. Labels shall indicate circuit or string and phase in accordance with the project drawings.

3.06 UTILITY INTERCONNECTION

- A. The Contractor shall coordinate and manage the utility interconnection agreement with the Owner’s approval. The Contractor shall submit the required authorization form with the utility to act on behalf of the Owner.
- B. The Contractor shall take all responsibility for the interconnect process upon contract execution until interconnect is complete, PTO has been achieved and no further work or coordination is required by the Utility.
- C. If the Owner has already submitted initial interconnection applications prior to the Contract being executed, the Contractor shall promptly review coordinate with the Utility, including making any proposed modifications to the system design.
- D. The Contractor should note that tariff grandfathering is key to District’s project strategy and the financial performance of the project. The Contractor shall ensure that any tariff grandfathering or other milestone achieved by the initial interconnect application is maintained.
- E. Should an issue arise that may jeopardize the initial interconnection scheme, tariff grandfathering, some other utility milestone, substantially increase interconnection costs or the ability to interconnect the project, the Contractor shall promptly notify the Owner and seek approval from Owner before making any changes to the interconnect application.

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- F. The Contractor shall inspect the existing main service switchgear to confirm suitability of the switchgear for the proposed interconnect scheme. Any substantial modification of the existing switchgear required to intertie the project shall be approved by the switchgear manufacturer or a Nationally Recognized Testing Laboratory. Where a NRTL approves modification of the switchgear, a field labeling report shall be provided to the Owner. The Contractor is responsible for obtaining switchgear manufacturer approval of any modification required to accommodate the connection, or NRTL approval and report.
- G. The solar PV system shall not be interconnected at the main service switchboard until written authorization from the Utility Company has been obtained. Unauthorized interconnections may result in injury to personnel and damage to equipment or property for which the Contractor may be liable.

3.07 INSTALLATION STANDARDS

- A. System Installation shall conform to the equipment manufacturers Installation Manual(s) and requirements or guidelines.
- B. All Local, State, and CEC codes shall be observed, including all industry standards related to the installation, operation, and maintenance of photovoltaic power systems.

3.08 TESTING

- A. Solar PV modules and inverters shall be factory tested for performance and the results shall be included with the equipment submittals and operations and maintenance manuals.
- B. Inverters shall be factory tested for performance and the results shall be included with the equipment submittals and in the operations and maintenance manuals.
- C. System testing of the installed photovoltaic array shall be performed on all system strings and recorded in commissioning documentation and the operation and maintenance manuals.
- D. Contractor shall megger test each array feeder before energizing to establish that no shorts to ground exist at any point in the solar PV arrays.
- E. Contractor shall perform ratio, polarity, and saturation tests performed on all voltage potential transformers (PTs) and current transformers (CTs). The polarity check shall be performed using high current injection test equipment. Contractor shall calibrate all current transducers to within 5 percent of nameplate accuracy using primary current injection method.
- F. System start-up procedure shall be as outlined by the Manufacturer’s Installation Manual(s).

3.09 COMMISSIONING

- A. Commissioning of PV Systems shall adhere to IEC 62446-1 requirements and shall include the following at a minimum:

1. CONDUCTORS

- a. AC & DC conductor inspection / megger. Insulation resistance and DC hi-pot testing of each AC and DC conductor, phase-to-phase and phase-to-ground.
- b. Wire management check
- c. DC string polarity, Voc & Isc testing and recording

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- d. Confirm all conduits & junction boxes are installed properly/watertight
 2. Inspection of DC fusing and disconnects
 3. Inspection of AC components: AC Disconnect, Main Switch Board, AC Combiner Panel Boards, Breakers, Fuses, Terminations, Phasing, OCPD operation, etc.
 4. Grounding & bonding system inspection and continuity testing
 5. INVERTERS
 - a. Inverter inspections and tests per manufacturer instructions
 - b. Inverter start-up and confirm proper inverter settings
 - c. Inverter output tests - Confirm PV system AC output as expected based on design, insolation and inverter readings
 6. IV Curve Trace, Performance testing and recording
 7. As-built sun access measurement at the corners of all arrays, minimum.
 8. THERMAL IMAGING
 - a. Check all electrical components while systems are energized
 - b. Spot check, Modules, Inverters, Disconnects, AC system, etc.
 9. Torque spot check on mechanical and electrical terminations
 10. Inspection of corrosion control measures
 11. Confirm signage and placards meet plans
 12. Workmanship evaluation
 13. Inspection of DAS / CT metering and monitoring equipment
 14. Weather station component inspection and performance audit
 15. Confirm web-based monitoring interface operations
 16. Commissioning of any other major electrical infrastructure installed on the project per manufacturer requirements
 17. Medium voltage equipment tested to NETA requirements
- B. PERFORMANCE TESTING**
1. Solar PV system testing shall comply with CPUC Electric Rule 21 testing procedures and requirements. Perform testing on “no-cloud” days to avoid performance fluctuations due to passing clouds. Contractor to provide all testing and certification/commissioning
 2. System start-up procedure shall be as outlined by the Manufacturer’s Installation Manual(s). An extended commissioning period as defined in the contract shall be provided for each system.
 3. Contractor shall complete performance testing to ASTM E2848-13 standard. Contractor shall define methodology within the protocol and obtain Owner's acceptance and notify owner before performing testing.
 4. Contractor shall perform power output test to confirm that completed solar PV system meets or exceeds intended output. Power output tests shall be conducted on at least five (5) separate days.

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5. Monitoring system shall be fully functional during performance testing. Contractor shall provide Owner access to the monitoring system prior to performance testing.

3.10 THIRD PARTY COMMISSIONING

- A. A third-party commissioning agent must be employed by the Contractor to perform an independent commissioning on the PV system.
- B. Contractor shall provide documentation, access to the system and any control/monitoring systems, and support the independent commissioning entity with their work.
- C. Contractor shall promptly correct punchlist items identified by the Owner and third-party commissioning agent.

3.11 INDEPENDENT COMMISSIONING

- A. An Independent, third-party commissioning agent may be employed by the Owner to perform an independent commissioning on the PV system.
- B. Contractor shall provide documentation, access to the system and any control/monitoring systems, and support the independent commissioning entity with their work.
- C. Contractor shall promptly correct punchlist items identified by the Owner and third-party commissioning agent.

3.12 DOCUMENTATION

- A. All commissioning, certification and testing reports shall be provided to the Owner within 15 days of completion of testing.
- B. The Contractor shall submit comprehensive closeout documentation as specified in Section 01 33 00: Submittal Process and Section 01 77 00, Closeout Procedures.

END OF SECTION 48 1400

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