

**SECTION 48 14 00  
SOLAR ENERGY ELECTRICAL POWER GENERATION SYSTEM**

**PART 1 - GENERAL**

**1.1 DESCRIPTION**

The requirements of this Section apply to all sections of Division 48 related to solar energy electrical power generation systems.

**1.2 RELATED WORK**

- A. Section 01 00 00, GENERAL REQUIREMENTS: General construction practices.
- B. Section 01 33 23, SHOP DRAWINGS, PRODUCT DATA, AND SAMPLES: Submittals.
- C. Section 26 05 11, REQUIREMENTS FOR ELECTRICAL INSTALLATIONS: General electrical installation requirements.
- D. Section 26 05 21, LOW-VOLTAGE ELECTRICAL POWER CONDUCTORS AND CABLES (600 VOLTS AND BELOW): Requirements for current conductors.
- E. Section 26 05 26, GROUNDING AND BONDING FOR ELECTRICAL SYSTEMS: Requirements for grounding.
- F. Section 26 05 33, RACEWAYS AND BOXES FOR ELECTRICAL SYSTEMS: Requirements for boxes, conduits, and raceways.
- G. Section 26 08 00, COMMISSIONING OF ELECTRICAL SYSTEMS: Requirements for commissioning the electrical system, subsystem, and equipment.
- H. Section 26 29 21, DISCONNECT SWITCHES: Requirements for disconnects.

**1.3 DEFINITIONS**

- A. Unless otherwise specified or indicated, electrical and electronics terms used in these specifications, and on the drawings, shall be defined in IEEE 100.
- B. Unless otherwise specified or indicated, solar energy conversion and solar photovoltaic energy system terms used in these specifications, and on the drawings, shall be defined in ASTM E772 and IEC 61836.

**1.4 QUALITY ASSURANCE**

- A. Solar Energy Electrical Power Generation System installer(s) shall demonstrate that they have successfully installed at least four projects that, in aggregate, equal or exceed the size of the proposed project. References shall be provided for each of these referenced projects.
- B. Refer to Paragraph, QUALIFICATIONS, in Section 26 05 11, REQUIREMENTS FOR ELECTRICAL INSTALLATIONS.

- C. Racking for solar photovoltaic system designs shall be prepared under the signature of a licensed Professional Engineer (PE). Where applicable, such as roof top installations, the PE shall also provide adequate review and structural analysis of the existing structure that will be supporting the proposed solar photovoltaic system. Among the documents that shall be submitted by the licensed engineer are environmental loading analyses (including wind, snow and where applicable, seismic) and the rack and substrate's ability to withstand these environmental forces. In the instance where the rack is installed on the ground, adequate information shall be presented to demonstrate the earth's ability to support the proposed design.
- D. If the system will be a tracking system, the mechanical and control systems shall be approved by the using entity. Preference shall be given to closed or hybrid-open/closed logic control for the tracking system.
- E. If paralleling arrangement is required, the system shall have anti-islanding capability thereby incapable of exporting power to the utility distribution system in the absence of utility power.
- F. Submit Solar Energy Electrical Power Generation System data package for the following items:
  - 1. Troubleshooting guide for solar photovoltaic systems
  - 2. Solar photovoltaic module warranty
  - 3. Operation instructions
  - 4. Preventive maintenance and inspection data, including a schedule for system operators
- G. Solar photovoltaic module warranty:
  - 1. **NOTE: Contractor is not responsible for solar module warranty on Government Furnished Solar Modules. Contractor only responsible for solar modules that are new and purchased by solar contractor. Contractor not responsible for power output of the Government furnished solar panels. The warranty requirements below are only for new solar modules provided and procured and installed by the Contractor.**
  - 2. Furnish five year manufacturer's warranty against defects in materials and workmanship.
  - 2. Furnish manufacturer's warranty with respect to power output that continues for a total of 25 years: the first 10 years at 90% minimum

rated power output and the balance of 15 years at 80% minimum rated power output.

3. PV modules shall be UL approved.

H. Where applicable, the batteries supplied shall be intended for use in photovoltaic solar systems.

**1.5 SUBMITTALS**

- A. Where proposed system shall be a Net Meter project, prepare appropriate applications and submittals to the COR. Where proposed system shall be connected in front of the meter and tied directly to the grid, prepare appropriate applications and submittals to the COR. In all cases, the local utility may have a requirement for further electrical studies, which may include power factor analysis, short circuit protection studies, grid wiring adequacy or capacities of upstream switches or transformers. If such requirements exist and are required by said utility, these requirements shall be fulfilled by the Contractor.
- B. Submit six copies in accordance with Section 01 33 23, SHOP DRAWINGS, PRODUCT DATA, AND SAMPLES, and with requirements in the individual specification sections, to the COR.
- C. Contractor shall make all necessary field measurements and investigations to assure that the equipment and assemblies will meet contract requirements.
- D. If equipment submitted differs in arrangement from that shown on the submittals, provide drawings that show the rearrangement of all associated systems. Approval will be given only if all features of the equipment and associated systems, including accessibility, are equivalent to that required by the contract and acceptable to the COR.
- E. Prior to submitting shop drawings for approval, Contractor shall certify in writing that manufacturers of all major items of equipment have each reviewed drawings and specifications from the applicable other manufacturers, and have jointly coordinated and properly integrated their equipment and controls to provide a complete and efficient installation.
- F. Submittals and shop drawings for independent items, containing applicable descriptive information, shall be furnished together and complete in a group. Coordinate and properly integrate materials and equipment in each group to provide a completely compatible and

efficient installation. Final review and approvals will be made only by groups.

- G. Shop Drawings: Include photovoltaic module structural supports, and instrument mounting and interconnections and all other components, parts and pieces required to complete the functioning assembly. Where applicable, include pre-fabricated assemblies such as inverter skids or racking assemblies, and shop drawings for foundations or other support structures.
- H. Product Data: Include detailed information for components of the solar energy system.
  - 1. Wiring
  - 2. Wiring Specialties
  - 3. DC-AC Inverter
  - 4. Solar Storage Battery Option
  - 5. Solar Modules
  - 6. Collector Supports
  - 7. Instrumentation
  - 8. Switch gear
  - 9. DC and AC disconnects, where applicable
  - 10. Combiner boxes, where applicable
  - 11. Rack system
  - 12. Monitoring systems, including appropriate interfacing with existing facility data collection systems.
- I. Certificates: Submit technical representative's certification that the installation has been implemented as intended by the system designer and where applicable, recommended by the manufacturer.
- J. Manufacturer's Instructions
- K. Operation and Maintenance Solar Energy Systems Data Package:
  - 1. Safety precautions
  - 2. Operator restart
  - 3. Startup, shutdown, and post-shutdown procedures
  - 4. Normal operations
  - 5. Emergency operations
  - 6. Environmental conditions
  - 7. Preventive maintenance plan and schedule
  - 8. Troubleshooting guides and diagnostic techniques
  - 9. Wiring and control diagrams

- 10. Maintenance and repair procedures
  - 11. Removal and replacement instructions
  - 12. Spare parts and supply list
  - 13. O&M submittal data
  - 14. Parts identification
  - 15. Testing equipment and special tool information
  - 16. Warranty information
  - 17. Testing and performance data
  - 18. Contractor information
- L. Closeout Submittals:
- 1. Posted operating instructions for solar photovoltaic energy system: provide for wiring identification codes and diagrams of solar photovoltaic systems, operating instructions, control matrix, and troubleshooting instructions.
  - 2. Solar photovoltaic system verification certificate per IEC 62446.

**1.6 APPLICABLE PUBLICATIONS**

- A. Publications listed below (including amendments, addenda, revisions, supplements and errata) form a part of this specification to the extent referenced. Publications are referenced in the text by the basic designation only.
- B. American Society for Testing and Materials (ASTM):
  - E772-11.....Standard Terminology of Solar Energy Conversion
  - E1038-10.....Standard Test Method for Determining Resistance of Photovoltaic Modules to Hail by Impact with Propelled Ice Balls
- C. Institute of Electrical and Electronics Engineers (IEEE):
  - 100-00.....The Authoritative Dictionary of IEEE Standards Terms, Seventh Edition
  - 519-92.....Recommended Practices and Requirements for Harmonic Control in Electric Power Systems
  - 937-07.....Recommended Practice for Installation and Maintenance of Lead-Acid Batteries for Photovoltaic (PV) Systems
  - 1013-07.....Recommended Practice for Sizing Lead-Acid Batteries for Stand-Alone Photovoltaic (PV) Systems

- 1361-03.....Guide for Selection, Charging, Test and Evaluation of Lead-Acid Batteries Used in Stand-Alone Photovoltaic (PV) Systems
- 1526-03.....Recommended Practice for Testing the Performance of Stand-Alone Photovoltaic Systems
- 1547-03.....Standard for Interconnecting Distributed Resources with Electric Power Systems
- 1561-07.....Guide for Optimizing the Performance and Life of Lead-Acid Batteries in Remote Hybrid Systems
- 1562-07.....Guide for Array and Battery Sizing in Stand-Alone Photovoltaic (PV) Systems
- 1661-07.....Guide for Test and Evaluation of Lead-Acid Batteries Used in Photovoltaic (PV) Hybrid Power Systems
- D. International Code Council (ICC):
  - IBC-12.....International Building Code
  - IFC-12.....International Fire Code
  - IRC-12.....International Residential Code
- E. International Electrotechnical Commission (IEC):
  - 60529-04.....Degrees of Protection Provided by Enclosures (IP Code); Ed 1.0
  - 61215-05.....Crystalline Silicon Terrestrial Photovoltaic (PV) Modules - Design Qualification and Type Approval; Ed 2.0
  - 61646-08.....Thin-Film Terrestrial Photovoltaic (PV) Modules - Design Qualification and Type Approval; Ed 2.0
  - 61730-1-04.....Photovoltaic (PV) Module Safety Qualification - Part 1: Requirements for Construction; Ed 1.0
  - 61836-07.....Solar Photovoltaic Energy Systems - Terms, Definitions and Symbols; Ed. 2.0
  - 62446-09.....Grid-Connected Photovoltaic (PV) Systems - Minimum Requirements for System Documentation, Commissioning Tests and Inspection; Ed 1.0
- F. International Organization for Standardization (ISO):
  - 9001-08.....Quality Management Systems - Requirements
- G. National Electrical Manufacturer's Association (NEMA):

- 250-08.....Enclosures for Electrical Equipment (1,000  
Volts Maximum)
- H. National Fire Protection Association (NFPA):
  - 70-11.....National Electrical Code (NEC)
- I. Underwriters Laboratories (UL):
  - 6-07.....Electrical Rigid Metal Conduit - Steel; Ed 14
  - 94-96.....Tests for Flammability of Plastic Materials for  
Parts in Devices and Appliances; Ed 5
  - 797-07.....Electrical Metallic Tubing - Steel; Ed 9
  - 969-95.....Standard for Marking and Labeling Systems; Ed 4
  - 1242-06.....Standard for Electrical Intermediate Metal  
Conduit - Steel; Ed 4
  - 1703-02.....Standard for Flat-Plate Photovoltaic Modules  
and Panels; Ed 3
  - 1741-10.....Standard for Inverters, Converters, Controllers  
and Interconnection System Equipment for Use  
with Distributed Energy Resources

**PART 2 - PRODUCTS**

**2.1 GENERAL**

- A. Provide materials to fabricate solar energy systems in accordance with this section. At the Contractor's option, provide factory-prefabricated solar equipment packages which include photovoltaic modules, batteries or other energy storage, inverters, and controls which meet the requirements of this section.
- B. The COR or local environmental entities may require environmental impact studies which may include, for example, effects upon wildlife. The Contractor shall determine which entity has jurisdiction over environmental matters and shall make appropriate inquiry and comply with all applicable regulations.

**2.2 GROUNDING**

- A. Array frame shall be installed in accordance with NFPA 70 NEC 250.
- B. Shall ground according to manufacturer instructions per UL 1703.
- C. DC Ground-Fault Protector:
  - 1. Shall be listed per UL 1703.
  - 2. Shall comply with requirements of the NEC to reduce fire hazards.
  - 3. Ungrounded DC solar photovoltaic arrays shall comply with the NEC.

**2.3 PV ARRAY CIRCUIT COMBINER BOX**

- A. Shall include internal overcurrent protection devices with dead front.
- B. Shall be contained in non-conductive NEMA Type 4X enclosure per NEMA 250.
- C. Up to 48 volts DC: Shall use DC breakers that meet NEC requirements for overcurrent protection, are ETL-tested, and UL-listed.
- D. Up to 600 volts DC, paralleling system: Shall use fuses instead of breakers.
- E. Shall be listed to UL 1741.
- F. Ground and pole-mounted arrays shall have a separate combiner box mounted to the pole itself.
- G. Where applicable, combiner box shall be a disconnecting combiner box.

**2.4 SWITCH/DISCONNECTING MEANS**

- A. Shall be in accordance with the NEC, as shown on the drawings, and as specified.
- B. Means of disconnect shall be UL-listed.
- C. Refer to COR for exact locations.
- D. Utility External Disconnect Switch (UEDS): Refer to COR as several states do not require UEDS for small solar photovoltaic systems as the inverter shall provide the same function per NFPA 70 NEC 690.61.

**2.5 BATTERY CHARGE CONTROLLER**

- A. Shall be capable of withstanding 25% over-amperage for limited time per the NEC.
- B. Charge controller or self-regulating system shall be required for a stand-alone system with battery storage. Charge controller's adjusting mechanism shall be accessible only to qualified persons.
- C. Shall be listed to UL 1741.
- D. Charge controller shall include maximum power point tracking (MPPT) and temperature compensation.
- E. Shall be manufactured in a facility with ISO 9001 certification.

**2.6 WIRING SPECIALTIES**

- A. Direct Current Conductor:
  - 1. If Exposed: Shall use USE-2, UF (inadequate at 60°C [140°F]), or SE, 90°C [194°F] wet-rated and sunlight-resistant (usually for tracking modules).

2. If in Conduit: Shall use RHW-2, THWN-2, or XHHW-2 90°C [194°F], wet-rated conductors required.
- B. Conduits and Raceways:
1. Shall use solid steel conduit listed per UL 6, UL 1242, UL 797 (as appropriate) except for tracking modules. Weather tight EMT installations shall be allowed for DC wiring in weather protected areas.
  2. Shall use expansion joints on long conduit runs.
  3. Cannot be installed on modules.
- C. Weather impacted enclosures shall be rated to NEMA 3R or better per NEMA 250.
- D. Cable Assemblies and Junction Boxes:
1. Shall be UL-listed.
  2. Shall be rated IP65 or IP67 per IEC 60529.
  3. Shall be rated to 5VA flammability per UL 94.
- E. Prohibited Wiring Materials: Not UL-listed, or listed materials used in unapproved environments.

#### **2.7 DC-AC INVERTER**

- A. Shall have stand-alone, utility-interactive, or combined capabilities.
- B. Shall be listed to UL 1741, per IRC M2302.4.
- C. Shall comply with IEEE 519 and IEEE 1547.
- D. Shall be listed per FCC Part 15 Class A (commercial) or Class B (residential): Unintended radiators.
- E. Shall include maximum power point tracking (MPPT) features.
- F. Shall include anti-islanding protection if paralleling arrangement is required.

#### **2.8 SOLAR PHOTOVOLTAIC (PV) MODULES**

- A. Minimum Performance Parameters as per IBC 1509.7.4, IRC M2302.3, UL 1703.
- B. Photovoltaic Panel Types:
  1. Monocrystalline: Listed to UL 1703, IEC 61215 and 61730, ISO 9000 or 9001; per NFPA 70 NEC 110.3, 690.4(D).
  2. Polycrystalline: Listed to UL 1703, IEC 61215 and 61730, ISO 9000 or 9001; per NFPA 70 NEC 110.3, 690.4(D).
  3. Thin-Film/Flexible: Listed to UL 1703, IEC 61646 and 61730, ISO 9000 or 9001; per NFPA 70 NEC 110.3, 690.4(D).

4. Building-Integrated & Solar Shingles: Listed to UL 1703, IEC 61646 and 61730, ISO 9000 or 9001, per NFPA 70 NEC 110.3, 690.4(D).
- C. Module and System Identification
  1. Module or Panel:
    - a. UL 969 defines weather resistance.
    - b. UL 1703 defines marking contents and format.
  2. Main Service Disconnect: per IFC 605.11.1.3, NFPA 70 NEC 690.13.
  3. Identification Content and Format: per NFPA 70 NEC 690.51.
  4. Identification for DC Conduit, Raceways, Enclosures, Cable Assemblies, and Junction Boxes: IFC 605.11.1, IFC 605.11.1.4
  5. Identification for Inverter: per NFPA 70 NEC 690.4(D), inverter shall be identified and listed for the application.
- D. Bypass diodes shall be built into each PV module either between each cell or each string of cells.
- E. Other Components: refer to UL 1703.
- F. Hail Protection: Compliant with testing procedure per ASTM E-1038.
- G. Lightning Protection: Shall ground according to manufacturer instructions per UL 1703.
- H. Access, Pathways, and Smoke Ventilation: per IFC 605.11.3, access and spacing requirements observed in order to: ensure access to the roof, provide pathways to specific areas of the roof, provide for smoke ventilation opportunities area, and, where applicable, provide emergency access egress from the roof.
- I. Fire Classification:
  1. IBC 1505.8 for building-integrated photovoltaic and solar shingles.
  2. IBC 1509.7.2 or IRC M2302.2.2: Although not technically enforceable, every effort shall be made to ensure the solar photovoltaic module is not combustible.

## **2.9 BATTERY OPTION**

- A. General: Adhere to NFPA 70 NEC 480, NEC 690 VIII, NEC 690.71(A); plus NEC 690.71(B) for dwellings.
- B. Off-Grid: Always use high-quality, industrial-grade, deep-cycle batteries.
- C. Grid-Interactive with Battery Backup: Best to use sealed-absorbed glass mat (AGM) batteries specifically designed for emergency standby or float service.
- D. Sizing: For stand-alone systems, size per IEEE 1013 and/or 1562.

- E. Installation and Maintenance: Follow practices per IEEE 937.
- F. Test and Evaluation:
  - 1. Stand-Alone System: Follow procedures per IEEE 1361.
  - 2. Hybrid System: Follow procedures per IEEE 1661.
- G. Optimize Performance and Life: Follow practices per IEEE 1561.
- H. Safety and Ventilation:
  - 1. Use protective enclosure and proper ventilation per the NEC.
  - 2. Exposed battery terminals and cable connections shall be protected, and live parts of batteries shall be guarded—the batteries should be accessible only to a qualified person via locked room, battery box, or other container.
  - 3. Spacing around battery enclosures and boxes and other equipment shall be at least 915 mm [36 inches]; batteries shall not be installed in living areas, or below enclosures, panelboards, or load centers.
  - 4. Prohibited are conductive cases for flooded, lead-acid batteries operating above 48-volt nominal. Battery racks shall have no conductive parts within 155 mm [6 inches] of the tops of cases.
  - 5. To prevent electric shock, storage batteries in dwellings shall operate at less than 50 volts (48-volt nominal battery bank). Live parts of any battery bank shall be guarded.
- I. Interconnection:
  - 1. Per NFPA 70 NEC Chapter 3, battery cables shall be a standard building wire type conductor. Welding and automobile “battery” cables (listed and non-listed) are forbidden.
  - 2. Flexible cables, listed for hard service use and moisture resistance, are permitted (not required) from battery terminals to nearby junction box and between battery cells. Flexible, highly-stranded building-wire type cables (USE/RHW and THW) are available. Consult with manufacturer data if battery terminals are compatible with flexible cables.

## **2.10 COLLECTOR SUPPORTS**

- A. Wind Resistance Requirement:
  - 1. For rack-mounted: IBC 1509.7.1
  - 2. For building-integrated photovoltaic and solar shingles: IBC 1507.17.3 and IRC R905.16.3
- B. Mechanical Load Requirement: UL 1703.

C. Ground and Pole Mount:

1. Shall require a Professional Engineer (PE) stamp on foundation design.
2. Where possible, shall have combiner boxes mounted directly to the pole itself.

**2.11 INSTRUMENTATION**

A. Charge Controller: See 2.2.G.

B. Meters: If grid-connected system, net smart meter provided by utility.

C. Sensors:

1. Temperature sensor shall be a component in the MPPT control system.
2. May install additional data acquisition sensors to measure irradiance, wind speed, and ambient and PV module temperatures. Any additional sensors shall require a conduit separate from the current conductor conduit.

D. Datalogger/Monitoring System: Shall be a packaged system capable of string-level monitoring or in the case of micro-inverters, capable of monitoring and logging an individual module's information.

**PART 3 - EXECUTION**

**3.1 INSTALLATION**

A. Install the solar photovoltaic system in accordance with the NEC, this section, and the printed instructions of the manufacturer per ICC IBC 1507.17.2. Prior to system start-up, ensure no copper wire remains exposed with the exception of grounding wire in certain circumstances per manufacturer instructions.

1. Refer to ICC IBC 1507.17.2; ICC IRC R905.16.2 for BIPV and Solar Shingles.
2. Refer to ICC IBC 1509.7.3; ICC IRC M2302.2 for rack-mounted PV.
3. Refer to ICC IBC 1507.1, 2; ICC IRC R905.16.3 for materials.

B. Wiring Installation: Workers shall be made aware that photovoltaic modules will be live and generating electricity when there is any ambient light source and shall take appropriate precautions. Utilize on site measurements in conjunction with engineering designs to accurately cut wires and layout before making permanent connections. Locate wires out of the way of windows, doors, openings, and other hazards. Ensure wires are free of snags and sharp edges that have the potential to compromise the wire insulation. If the system is roof-mounted it shall have direct current ground fault protection according to NEC 690.5.

Ensure breakers in combiner box are in the off position (or fuses removed) during combiner box wiring.

- C. Instrumentation: Install instruments as recommended by the control manufacturers. Locate control panels inside mechanical room.
- D. Building-Integrated Photovoltaic Installations: Building-integrated photovoltaic modules/shingles shall be installed in accordance with the manufacturer's installation instructions per IBC 1507.17.2.
- E. Rack-Mounted Photovoltaic Installations: Rack-mounted photovoltaic modules shall be installed in accordance with the manufacturer's installation instructions per IBC 1507.17.3.
- F. Ground and Pole-Mounted Photovoltaic Installations: If structure is used as equipment grounding conductor, ensure compliance with NFPA 70 NEC 250.136 and 690.43. Wiring shall not be readily accessible.
- G. Tracking System Installations: Disconnect shall be within sight of the tracking motor.

### **3.2 FIELD QUALITY CONTROL**

- A. Field Inspection: Prior to initial operation, inspect the photovoltaic system for conformance to drawings, specifications and NFPA 70. Inspect the following information on each collector:
  - 1. Manufacturer's name or trademark
  - 2. Model name or number
  - 3. Certifying agency label and rating.
- B. Tests: Provide equipment and apparatus required for performing tests. Correct defects disclosed by the tests and repeat tests. Conduct testing in the presence of the //Contracting Officer// //QC Representative// //COR.
  - 1. Module String Voltage Test: Prior to connecting wiring to the combiner box, use a digital multimeter to ensure each series string's polarity is correct. Tests shall be performed in accordance with IEC 62446.
  - 2. Operation Tests: Perform tests on electrical systems, in accordance with the manufacturer's written recommendations. Tests for stand-alone systems shall be performed per IEEE 1526.

### **3.3 FOLLOW-UP VERIFICATION**

- A. Upon completion of acceptance checks, settings, and tests, the Contractor shall show by demonstration in service that the solar

photovoltaic electrical power generation system is in good operating condition and properly performing the intended function.

**3.4 COMMISSIONING**

- A. Contractor shall coordinate with electrical utility to establish interconnection agreement if system is grid-tied.
- B. Connect the solar array to the electrical utility grid only after receiving prior approval from the utility company.
- C. Only qualified personnel shall connect the solar array to the utility grid.

**3.5 INSTRUCTION**

- A. A complete set of operating instructions for the solar photovoltaic electrical power generation system shall be laminated or mounted under acrylic glass and installed in a frame near the equipment.
- B. Furnish the services of a factory-trained technician for one, 4-hour training period for instructing personnel in the maintenance and operation of the solar photovoltaic electrical power generation system, on the dates requested by the COR.

---END---