SECTION 48 14 00
SOLAR ENERGY ELECTRICAL POWER GENERATION SYSTEM

SPEC WRITER NOTES:
Delete between // --- // if not applicable to project. Also delete any other item or paragraph not applicable in the section and renumber the paragraphs.

PART 1 - GENERAL

1.1 DESCRIPTION

A. This section specifies the furnishing, installation, connection, testing, and commissioning of solar energy electrical power generation systems.

B. 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 01 91 00, GENERAL COMMISSIONING REQUIREMENTS: General requirements for commissioning.

//D. Section 13 05 41, SEISMIC RESTRAINT REQUIREMENTS FOR NON-STRUCTURAL COMPONENTS: Requirement for seismic restraint for nonstructural components.//

E. Section 26 05 11, REQUIREMENTS FOR ELECTRICAL INSTALLATIONS: Requirements that apply to all sections of Division 26.

F. Section 26 05 19, LOW-VOLTAGE ELECTRICAL POWER CONDUCTORS AND CABLES: Requirements for low-voltage conductors.

G. Section 26 05 26, GROUNDING AND BONDING FOR ELECTRICAL SYSTEMS: Requirements for personnel safety and requirements for providing a low impedance path for possible ground fault currents.

H. Section 26 05 33, RACEWAYS AND BOXES FOR ELECTRICAL SYSTEMS: Requirements for boxes, conduits, and raceways.

I. Section 26 08 00, COMMISSIONING OF ELECTRICAL SYSTEMS: Requirements for commissioning the electrical system, subsystems, and equipment.

J. Section 26 29 21, ENCLOSED SWITCHES AND CIRCUIT BREAKERS: Requirements for enclosed disconnect switches.

1.3 DEFINITIONS

A. Unless otherwise specified or indicated, electrical and electronics terminology used in these specifications, and on the drawings, shall be as defined in IEEE 100 CD.

B. Unless otherwise specified or indicated, solar energy conversion and solar photovoltaic energy system terminology used in these specifications, and on the drawings, shall be as defined in ASTM E772.

1.4 QUALITY ASSURANCE

A. Products and Services pertaining to this specification shall comply with Paragraph, QUALIFICATIONS, in Section 26 05 11, REQUIREMENTS FOR ELECTRICAL INSTALLATIONS.

B. Solar Energy Electrical Power Generation System installer(s) shall demonstrate that they have successfully installed at least four projects within the past five years that, in aggregate, equal or exceed the size of the proposed project. References shall be provided for each of the referenced qualified projects.

C. Supports and racking for solar photovoltaic system designs shall be prepared under the seal of a licensed Professional Structural Engineer (PE). Where applicable, such as roof top installations, the engineer 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 engineer are environmental loading analyses (including wind, snow, hail, 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 desired, the system shall have anti-islanding capability such that it is incapable of exporting power to the utility distribution system in the absence of utility power. Paralleling must be approved by serving electric utility. Provide written correspondence from the utility confirming its requirements.

F. Investigate whether the //Resident Engineer// //Contracting Officer's Representative (COR)// or local environmental entities require environmental impact studies which may include, but are not limited to, 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.

G. Investigate any other local ordinances that may apply to installation of a solar energy electrical generating system in the proposed location. Bring any conflicts with the drawings and specifications to the attention of the //Resident Engineer// //COR//.

H. Warranties: The solar energy electrical generating system shall be subject to the terms of FAR Clause 52.246-21, except that the warranty period shall be as noted for the items below:

1. Solar photovoltaic modules and inverter: 10 year manufacturer's warranty against defects in materials and workmanship.
2. Power output: 25 year manufacturer's power output warranty, with the first 10 years at 90% minimum rated power output and the balance of the 25 years at 80% minimum rated power output.

//3. Existing roof: Notify warrantor of existing roofing system on prior to beginning work and on completion of work, and obtain documentation verifying that existing roofing system has been inspected and warranty remains in effect. Submit documentation at project closeout.//

1.5 SUBMITTALS

A. Where proposed system shall be a Net Meter project, prepare appropriate applications and submittals to the //Resident Engineer// //COR//. Where proposed system shall be connected before the serving electric utility's meter and tied directly to the grid, prepare appropriate applications and submittals to the //Resident Engineer// //COR//. In all cases, the serving electric utility may have a requirement for further electrical studies, which may include or not be limited to power factor analysis, short circuit protection studies, grid wiring adequacy, or capacities of upstream equipment. If such requirements exist and are required by the serving electric utility, these requirements shall be fulfilled by the Contractor. Provide written documentation confirming the utility's approval of the interconnection of the solar energy electrical power generation system with the utility system.

B. Submittals shall comply with paragraph, SUBMITTALS, in Section 26 05 11, REQUIREMENTS FOR ELECTRICAL INSTALLATIONS, and the following requirements:

1. Shop Drawings:

a. Submit sufficient information to demonstrate compliance with drawings and specifications.
b. Include electrical ratings, dimensions, mounting details, materials, required clearances, terminations, weight, wiring and connection diagrams, accessories, and nameplate data.
c. Include shop drawings for foundations and other support structures.

2. Product Data:
a. Include detailed information for components of the solar energy electrical generation system.
1. Wiring.
2. Inverter.
3. Photovoltaic modules.
4. Rack and support assemblies.
5. Instrumentation.
6. Switchgear.
7. DC and AC disconnects.
8. Combiner boxes.
9. Monitoring systems // including appropriate interfacing with existing facility data collection systems//.

SPEC WRITER NOTE: Include the following paragraph for projects in moderate-high, high and very high seismic zones as listed in Table 4 of VA Handbook H-18-8, Seismic Design Requirements.

//b. Certification from the manufacturer that the system has been seismically tested to International Building Code requirements. Certification shall be based upon simulated seismic forces on a shake table or by analytical methods, but not by experience data or other methods.//

3. Manuals:
a. Submit, simultaneously with the shop drawings, complete maintenance and operating manuals including technical data sheets, wiring diagrams, and information for ordering replacement parts.
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. Tracking systems (where applicable).
13. Spare parts and supply list.
14. Parts identification.
15. Testing equipment and special tool information.
16. Warranty information.
17. Testing and performance data.
18. Contractor information.

b. If changes have been made to the maintenance and operating manuals originally submitted, then submit updated maintenance and operating manuals two weeks prior to the final inspection.

4. Certifications: Two weeks prior to final inspection, submit the following.

a. Certification by the manufacturers of all major items of the solar energy electric generation system that the system conforms to the requirements of the drawings and specifications, and that they have jointly coordinated and properly integrated their equipment and controls to provide a complete and functional installation.

b. Certification by the Contractor that the solar energy electric generation system has been properly installed, adjusted, tested, commissioned, and warrantied. Contractor shall make all necessary field measurements and investigations to ensure that the equipment and assemblies meet contract requirements.

5. Estimated Annual Power Output: Submit calculated annual power output for each of the proposed solar photovoltaic systems. Provide independent calculations for each fixed, single-axis tracking, or double-axis tracking system.

C. If equipment submitted differs in arrangement from that shown on the drawings, 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 //Resident Engineer// //COR//.

D. Submittals and shop drawings for independent but related items shall be furnished together and complete in a group. Coordinate and properly integrate materials and equipment in each group. Final review and approval will be made only by groups.

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):

E772-15.....Standard Terminology of Solar Energy Conversion

E1038-15.....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 CD-13.....The Authoritative Dictionary of IEEE Standards Terms

519-14.....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

1361-14.....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-15.....International Building Code

IFC-15.....International Fire Code

E. National Electrical Manufacturer's Association (NEMA):

250-14.....Enclosures for Electrical Equipment (1,000 Volts Maximum)

F. National Fire Protection Association (NFPA):

70-17.....National Electrical Code (NEC)

G. Underwriters Laboratories (UL):

6-07.....Electrical Rigid Metal Conduit – Steel

94-13.....Tests for Flammability of Plastic Materials for Parts in Devices and Appliances; Ed 6

797-07.....Electrical Metallic Tubing – Steel

969-17.....Standard for Marking and Labeling Systems

1242-14.....Standard for Electrical Intermediate Metal Conduit – Steel

1703-02.....Standard for Flat-Plate Photovoltaic Modules and Panels

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 functioning photovoltaic system in accordance with ASTM, IEEE, NEMA, NFPA, and UL, as specified in this section, and as shown on the drawings.

B. Factory-prefabricated solar equipment packages which include photovoltaic modules, batteries or other energy storage, inverters, and controls and which meet the requirements of this section are acceptable.

2.2 GROUNDING

A. All applicable components of the solar energy electrical power generating system must be grounded per latest NEC requirements.

B. DC Ground-Fault Protector:

1. Shall be listed per UL 1703.

2. Shall comply with requirements of the NEC.

2.3 PHOTOVOLTAIC ARRAY CIRCUIT COMBINER BOX

A. Shall be listed to UL 1741.

B. Shall include internal overcurrent protection devices with dead front.

C. Shall be contained in non-conductive NEMA Type 4X enclosure.

D. Up to 48 volts DC: Shall use UL-listed DC breakers that meet NEC requirements for overcurrent protection.

E. Up to 600 volts DC, paralleling system: Shall use fuses instead of breakers.

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

SPEC WRITER NOTE: Certain inverter manufacturers include a DC fused disconnect as part of their inverters. In those cases, a separate disconnect will not be required.

A. Shall be UL-listed, in accordance with the NEC, as shown on the drawings, and as specified.

B. Utility External Disconnect Switch (UEDS): Refer to //Resident Engineer// //COR//, as several states do not require UEDS for small solar photovoltaic systems if the inverter provides the same function per NEC. Coordinate requirements with serving electric utility.

2.5 WIRING SPECIALTIES

A. Direct Current Conductors:

1. If Exposed: Shall be USE-2, UF (inadequate at 60°C [140°F]), or SE, 90°C [194°F] wet-location rated and sunlight-resistant (usually for tracking modules).
2. If in Conduit: Shall be RHW-2, THWN-2, or XHHW-2 90°C [194°F], wet-location rated.

B. Conduits and Raceways:

1. Shall use steel conduit listed per UL 6, UL 1242, UL 797 (as appropriate), except for tracking modules. Weathertight EMT installations shall be allowed for DC wiring in weather-protected areas.
2. Shall use expansion joints on long conduit runs.
3. Shall not be installed on photovoltaic modules.

C. Enclosures subject to weather shall be rated NEMA 3R or better.

D. Cable Assemblies and Junction Boxes:
   1. Shall be UL-listed.
   2. Shall be rated to 5VA flammability per UL 94.
E. Prohibited Wiring Materials: Those which are not UL-listed, or listed materials used in environments outside those covered in their listing.

2.6 DC-AC INVERTER

A. Shall be listed to UL 1741.`
B. Shall comply with IEEE 519 and IEEE 1547.
C. Shall be listed per FCC Part 15 Class A.1.
D. Shall have stand-alone, utility-interactive, or combined capabilities.
E. Shall include maximum power point tracking (MPPT) features.
F. Shall include anti-islanding protection if paralleling arrangement is required.

2.7 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.
   2. Polycrystalline: Listed to UL 1703.
   3. Thin-Film/Flexible: Listed to UL 1703.
   4. Building-Integrated & Solar Shingles: Listed to UL 1703.
C. Module and System Identification
   1. Module or Panel:
      a. Listed to UL 969 for weather resistance.
      b. Listed to UL 1703 for marking contents and format.
   2. Main Service Disconnect: per NEC.
   3. Identification Content and Format: per NEC.
   4. Identification for DC Conduit, Raceways, Enclosures, Cable Assemblies, and Junction Boxes: IFC 605.
   5. Identification for Inverter: per NEC.
D. Bypass diodes shall be built into each PV module either between each cell or each string of cells.
E. Other Components: per 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 605.3, access and spacing requirements must be 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: Although not technically enforceable, every effort shall be made to ensure the solar photovoltaic module is not combustible.

//2.8 BATTERY CHARGE CONTROLLER

A. Listed per UL 1741.

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 capable of withstanding 25% over-amperage while charging for limited time per the NEC.

D. Charge controller shall include maximum power point tracking (MPPT) and temperature compensation.//

//2.9 BATTERY

A. General: Comply with NEC. Flooded lead-acid, captive electrolyte lead acid and nickel-cadmium are acceptable. Consider climate when selecting battery type.

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. 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 reduce risk of 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 NEC, battery cables shall be a standard building wire type conductor. Welding and automobile "battery" cables (listed and non-listed) are prohibited.
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. Battery terminals shall be compatible with flexible cables.//

2.10 COLLECTOR SUPPORTS

A. Wind Resistance Requirement:

1. For rack-mounted: per IBC 1509.7.1.
2. For building-integrated photovoltaic and solar shingles: IBC 1507.17.3.

B. Mechanical Load Requirement: per UL 1703.

C. Ground and Pole Mount:

1. Foundations shall be designed by a licensed Professional Structural Engineer (PE).
2. Where possible, combiner boxes shall be mounted directly to the pole itself.

2.11 INSTRUMENTATION

A. Meters: If applicable and system is grid-connected, use net smart meter provided by the serving electric utility.

B. 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.

C. Data logger/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.

B. Prior to system start-up, ensure no copper wire remains exposed with the exception of grounding wire as allowed in certain circumstances per manufacturer's instructions.

//C. In seismic areas, systems shall be adequately anchored and braced per details on structural contract documents to withstand seismic forces at the locations where installed.//

D. 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. All cabling shall be mechanically fastened. If the system is roof-mounted it shall have direct current ground fault protection according to NEC. Ensure breakers in combiner box are in the off position (or fuses removed) during combiner box wiring.

E. Instrumentation: Install instruments as recommended by the manufacturer. Locate control panels inside a room accessible only to qualified persons.

F. Building-Integrated Photovoltaic Installations: Building-integrated photovoltaic modules/shingles shall be installed in accordance with the manufacturer's installation instructions.

G. Rack-Mounted Photovoltaic Installations: Rack-mounted photovoltaic modules shall be installed in accordance with the manufacturer's installation instructions.

H. Ground and Pole-Mounted Photovoltaic Installations: If structure is used as equipment grounding conductor, ensure compliance with NEC. Wiring shall not be readily accessible.

I. Tracking System Installations: Disconnect shall be within sight of the tracking motor.

J. Provide safety signage per NEC.

//K. Remove, replace, patch, and repair existing roofing materials and surfaces cut or damaged during installation of the solar energy electrical power generation system, by methods and with materials so as not to void existing roofing system warranty. Notify roof warrantor before proceeding.//

3.2 FIELD QUALITY CONTROL

A. Field Inspection: Perform in accordance with manufacturer's recommendations. Prior to initial operation, inspect the solar energy electrical power generation system for conformance to drawings, specifications, and NEC. In addition, include the following:

1. Visual Inspection and Tests:
   a. Compare equipment nameplate data with specifications and approved shop drawings.
   b. Inspect physical, electrical, and mechanical condition.
   c. Verify required area clearances.
   d. Verifying tightness of accessible bolted electrical connections by calibrated torque-wrench method, or performing thermographic survey after energization.
   e. Verify the correct operation of all sensing devices, alarms, and indicating devices.
   f. Verify that all cable entries from top of junction boxes are sealed per junction box rating.
   g. Verify all connections and integrity of printed circuit boards in all applicable junction boxes.

B. Tests: Provide equipment and apparatus required for performing tests. Correct defects disclosed by the tests and repeat tests. Conduct tests in the presence of the //Resident Engineer// //COR//.

1. Module String Voltage Test: Prior to connecting wiring to the combiner box, use a digital multi-meter to ensure each series string's polarity is correct.

2. Operational Tests: Perform tests 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. Comply with the requirements of Section 01 91 00, GENERAL COMMISSIONING REQUIREMENTS.

B. If the system is grid-tied, the Contractor shall coordinate with the serving electric utility to establish an interconnection agreement.

C. Connect the solar photovoltaic electrical power generation system to the serving electric utility grid only after receiving prior approval from the utility company.

D. Only qualified personnel shall connect the solar photovoltaic electrical power generation system to the serving electric 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 date requested by the //Resident Engineer// //COR//.

---END---