SECTION TABLE OF CONTENTS

DIVISION 26 - ELECTRICAL

SECTION 26 31 00

SOLAR PHOTOVOLTAIC (PV) COMPONENTS

05/15

-- End of Section Table of Contents --

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USACE / NAVFAC / AFCEC / NASA **UFGS 26 31 00 (May 2015)**

Preparing Activity: NAVFAC

UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated April 2021
****

SECTION 26 31 00

SOLAR PHOTOVOLTAIC (PV) COMPONENTS
05/15

****
NOTE: This specification covers the requirements for solar photovoltaic (PV) systems, and related equipment and materials.

Adhere to UFC 1-300-02 Unified Facilities Guide Specifications (UFGS) Format Standard when editing this guide specification or preparing new project specification sections. Edit this guide specification for project specific requirements by adding, deleting, or revising text. For bracketed items, choose applicable item(s) or insert appropriate information.

Remove information and requirements not required in respective project, whether or not brackets are present.

Comments and suggestions on this guide specification are welcome and should be submitted as a Criteria Change Request (CCR).
****

****
NOTE: Show the following information on the project drawings:

1. Mounting surface features (i.e. drains, hatches, vents, and lightning protection).

2. Locations of solar PV modules, inverters, combiner and junction boxes, conduits and raceways, system monitoring panels, data acquisition sensors, cable tags with legend, control panels, overcurrent protection, lightning arrestors, and other related equipment and materials.

3. Circuit wiring diagram of solar PV energy system.

4. Mounting structure system for solar PV modules, including building roof or ground.

5. Number, location, and letter designation of

nameplates.
****

PART 1 GENERAL

1.1 REFERENCES

****
NOTE: This paragraph is used to list the publications cited in the text of the guide specification. The publications are referred to in the text by basic designation only and listed in this paragraph by organization, designation, date, and title.

Use the Reference Wizard's Check Reference feature when you add a Reference Identifier (RID) outside of the Section's Reference Article to automatically place the reference in the Reference Article. Also use the Reference Wizard's Check Reference feature to update the issue dates.

References not used in the text will automatically be deleted from this section of the project specification when you choose to reconcile references in the publish print process.
****

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

AMERICAN CONCRETE INSTITUTE (ACI)

ACI 318	(2014; Errata 1-2 2014; Errata 3-5 2015; Errata 6 2016; Errata 7-9 2017) Building Code Requirements for Structural Concrete (ACI 318-14) and Commentary (ACI 318R-14)
ACI 318M	(2014; ERTA 2015) Building Code Requirements for Structural Concrete & Commentary

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

ANSI C12.1	((2014; Errata 2016) Electric Meters - Code for Electricity Metering

AMERICAN SOCIETY OF CIVIL ENGINEERS (ASCE)

ASCE 7-16	(2017; Errata 2018; Supp 1 2018) Minimum Design Loads and Associated Criteria for Buildings and Other Structures

AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS (ASHRAE)

ASHRAE 189.1	(2014) Standard for the Design of High-Performance Green Buildings Except

ASTM INTERNATIONAL (ASTM)

ASTM C260/C260M	(2010a; R 2016) Standard Specification for Air-Entraining Admixtures for Concrete
ASTM D149	(2020) Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials at Commercial Power Frequencies
ASTM D257	(2014) Standard Test Methods for D-C Resistance or Conductance of Insulating Materials
ASTM D709	(2017) Standard Specification for Laminated Thermosetting Materials
ASTM D882	(2012) Tensile Properties of Thin Plastic Sheeting
ASTM D903	(1998; R 2017) Standard Test Method for Peel or Stripping Strength of Adhesive Bonds
ASTM D1876	(2008; R 2015; E 2015) Standard Test Method for Peel Resistance of Adhesives (T-Peel Test)
ASTM D2244	(2016) Standard Practice for Calculation of Color Tolerances and Color Differences from Instrumentally Measured Color Coordinates
ASTM D2765	(2016) Standard Test Methods for Determination of Gel Content and Swell Ratio of Crosslinked Ethylene Plastics
ASTM D5870	(2016) Standard Practice for Calculating Property Retention Index of Plastics
ASTM D7567	(2009) Standard Test Method for Determining Gel Content in Crosslinked Ethylene Plastics Using Pressurized Liquid Extraction
ASTM E308	(2017) Standard Practice for Computing the Colors of Objects by Using the CIE System
ASTM E424	(1971; R 2015) Standard Test Methods for Solar Energy Transmittance and Reflectance (Terrestrial) of Sheet Materials
ASTM E772	(2015) Standard Terminology of Solar Energy Conversion
ASTM E1171	(2015) Standard Test Methods for Photovoltaic Modules in Cyclic Temperature

and Humidity Environments

ASTM F1249 (2020) Standard Test Method for Water Vapor Transmission Rate Through Plastic Film and Sheeting Using a Modulated Infrared Sensor

ASTM G155 (2013) Standard Practice for Operating Xenon Arc Light Apparatus for Exposure of Non-Metallic Materials

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

IEEE 1547 (2018) Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces

IEEE C2 (2017; Errata 1-2 2017; INT 1 2017) National Electrical Safety Code

IEEE Stds Dictionary (2009) IEEE Standards Dictionary: Glossary of Terms & Definitions

INTERNATIONAL CODE COUNCIL (ICC)

ICC IBC (2021) International Building Code

INTERNATIONAL ELECTRICAL TESTING ASSOCIATION (NETA)

NETA ATS (2021) Standard for Acceptance Testing Specifications for Electrical Power Equipment and Systems

INTERNATIONAL ELECTROTECHNICAL COMMISSION (IEC)

IEC 61215 (2005; ED 2.0) Crystalline Silicon Terrestrial Photovoltaic (PV) Modules - Design Qualification and Type Approval

IEC 61646 (2008; ED 2.0) Thin-Film Terrestrial Photovoltaic (PV) Modules – Design Qualification and Type Approval

IEC 61730-1 (2016) Photovoltaic (PV) Module Safety Qualification – Part 1: Requirements for Construction

IEC 61853-1 (2011; ED 1.0) Photovoltaic (Pv) Module Performance Testing and Energy Rating – Part 1: Irradiance and Temperature Performance Measurements and Power Rating

IEC TS 62727 (2012; ED 1.0) Photovoltaic Systems – Specifications for Solar Trackers

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION (ISO)

ISO 9001 (2015) Quality Management Systems-

Requirements

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

NEMA 250	(2018) Enclosures for Electrical Equipment (1000 Volts Maximum)
NEMA IEC 60529	(2004) Degrees of Protection Provided by Enclosures (IP Code)

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 1	(2021) Fire Code
NFPA 70	(2020; ERTA 20-1 2020; ERTA 20-2 2020; TIA 20-1; TIA 20-2; TIA 20-3; TIA 20-4) National Electrical Code
NFPA 70E	(2021) Standard for Electrical Safety in the Workplace
NFPA 780	(2017) Standard for the Installation of Lightning Protection Systems

NATIONAL ROOFING CONTRACTORS ASSOCIATION (NRCA)

NRCA 3767	(2012) NRCA Guidelines for Roof Systems With Rooftop Photovoltaic Components

PILE DRIVING CONTRACTORS ASSOCIATION (PDCA)

PDCA Specification 103	(2007) Installation Specification for Driven Piles

SANDIA NATIONAL LABORATORIES (SAND)

SAND2007-5036	(2007) Performance Model for Grid-Connected. Photovoltaic Inverters

UNDERWRITERS LABORATORIES (UL)

UL 969	(2017; Reprint Mar 2018) UL Standard for Safety Marking and Labeling Systems
UL 1449	(2021) UL Standard for Safety Surge Protective Devices
UL 1703	(2002; Reprint Jun 2016) UL Standard for Safety Flat-Plate Photovoltaic Modules and Panels
UL 1741	(2010; Reprint Jan 2015) UL Standard for Safety Inverters, Converters, Controllers and Interconnection System Equipment for Use With Distributed Energy Resources
UL 2703	(2015; Reprint Dec 2019) UL Standard for Safety Mounting Systems, Mounting Devices, Clamping/Retention Devices, And Ground

	Lugs For Use With Flat-Plate Photovoltaic Modules And Panels
UL Electrical Construction	(2012) Electrical Construction Equipment Directory

1.2 RELATED REQUIREMENTS

Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM apply to this section with additions and modifications specified herein.

[1.2.1 Interconnection

****
NOTE: To expedite interconnection and activity, solicit local utility point of contact, if known.
****

Coordinate with local utility interconnection and activity. [Point of contact [_____].]

]1.3 DEFINITIONS

a. Unless otherwise specified or indicated, electrical and electronics terms used in these specifications, and on the drawings, are as defined in the IEEE Stds Dictionary.

b. Unless otherwise specified or indicated, solar energy conversion terms used in these specifications, and on the drawings, are as defined in ASTM E772.

1.4 SUBMITTALS

****
NOTE: Review Submittal Description (SD) definitions in Section 01 33 00 SUBMITTAL PROCEDURES and edit the following list, and corresponding submittal items in the text, to reflect only the submittals required for the project. The Guide Specification technical editors have classified those items that require Government approval, due to their complexity or criticality, with a "G." Generally, other submittal items can be reviewed by the Contractor's Quality Control System. Only add a "G" to an item if the submittal is sufficiently important or complex in context of the project.

For Army projects, fill in the empty brackets following the "G" classification, with a code of up to three characters to indicate the approving authority. Codes for Army projects using the Resident Management System (RMS) are: "AE" for Architect-Engineer; "DO" for District Office (Engineering Division or other organization in the District Office); "AO" for Area Office; "RO" for Resident Office; and "PO" for Project Office. Codes following the "G" typically are not used for Navy, Air Force, and NASA projects.

The "S" classification indicates submittals required as proof of compliance for sustainability Guiding Principles Validation or Third Party Certification and as described in Section 01 33 00 SUBMITTAL PROCEDURES.

Choose the first bracketed item for Navy, Air Force, and NASA projects, or choose the second bracketed item for Army projects.

****

Government approval is required for submittals with a "G" or "S" classification. Submittals not having a "G" or "S" classification are [for Contractor Quality Control approval.][for information only. When used, a code following the "G" classification identifies the office that will review the submittal for the Government.] Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-02 Shop Drawings

Schematic Diagrams; G[,[_____]]

Interconnection Diagrams; G[,[_____]]

Installation Drawings; G[,[_____]]

SD-03 Product Data

Combiner Boxes; G[,[_____]]

Disconnects; G[,[_____]]

Inverters; G[,[_____]]; S

String Inverter CEC Efficiency; G[,[_____]]; S

Microinverter CEC Efficiency; G[,[_____]]; S

Roof Mounting Structure for Modules (Racking); G[,[_____]]

Ground Mounting Structure for Modules; G[,[_____]]

Photovoltaic Module Backsheet; G[,[_____]]

Photovoltaic Module Encapsulent; G[,[_____]]

Photovoltaic Modules; G[,[_____]]; S

Photovoltaic Wire; G[,[_____]]

System Monitoring; G[,[_____]]

SD-05 Design Data

System Operation; G[,[_____]]

Calculations; G[,[_____]]; S

System Performance Calculations; G[,[_____]]; S

SD-06 Test Reports

NABCEP Acceptance Checks and Tests; G[,[_____]]

NETA Acceptance Checks and Tests; G[,[_____]]

SD-07 Certificates

Installer; G[,[_____]]

Materials; G[,[_____]]

Warranty; G[,[_____]]

Cybersecurity Equipment Certification;[; G][; G, [_____]]

Cybersecurity Installation Certification;[; G][; G, [_____]]

SD-08 Manufacturer's Instructions

Installation Instructions; G[,[_____]]

SD-10 Operation and Maintenance Data

Electrical Systems, Data Package 5; G[,[_____]]

Training Course; G[,[_____]]

1.5 MAINTENANCE MATERIAL SUBMITTALS

Comply with requirements specified in Section 01 78 00 CLOSEOUT SUBMITTALS.

1.6 QUALITY ASSURANCE

1.6.1 Regulatory Requirements

In each of the publications referred to herein, consider the advisory provisions to be mandatory, as though the word, "shall" had been substituted for "should" wherever it appears. Interpret references in these publications to the "authority having jurisdiction," or words of similar meaning, to mean the Contracting Officers. Provide equipment, materials, installation, and workmanship in accordance with the mandatory and advisory provisions of NFPA 70 unless more stringent requirements are specified or indicated.

1.6.2 Installation Drawings

In addition to requirements in Section 01 33 00 SUBMITTAL PROCEDURES, include the following:

a. Submit drawings for government approval prior to equipment construction or integration.

b. Submit shop drawings at a minimum of 279.4 by 431.8 mm 11 by 17 inches in size.

c. All details legible and all text no smaller than 2.54 mm 0.1 inches in height on any drawing. As needed, provide enlargements to ensure

clarity of intent.

d. Shop drawings must include [one][three]-wire diagrams and installation details of photovoltaic (PV) system equipment indicating location as proposed in design drawings, layout and arrangement of PV modules, support and mounting mechanism, inverters, combiner boxes, AC and DC disconnects, equipment enclosures, conduits, monitors, meters, security systems, and all other accessories associated with the installation of the PV system. Wiring diagrams must identify circuit terminals and indicate the internal wiring for each item of equipment and the interconnection between each equipment item.

e. Shop drawings may include legible copies of manufacturer's product literature, with selected items and specifications highlighted thereon.

f. Modifications to original drawings made during installation must be immediately recorded for inclusion into the as-built drawings. When items have changed relative to the approved design, the designer must provide certification indicating that the changes will not negatively affect the system's operation or the structure supporting the system.

1.6.3 System Operation

Provide a complete description of the function of each component including PV modules, DC wiring, combiner boxes, inverters, AC wiring, AC and DC disconnect switches, and monitoring system. Provide a discussion of the overall system operation.

1.6.4 Installer

Submit NABCEP (North American Board of Certified Energy Practitioners) PV Installation Professional certification, and a resume with references that details least four successful projects that, in aggregate, equal or exceed the size of the proposed project.

1.6.5 Materials

Provide materials and equipment that are products of manufacturers regularly engaged in the production of such products which are of equal material, design and workmanship. Submit proof of compliance with requirements of UL, where material or equipment is specified to comply. The label of or listing in UL Electrical Construction Directory will be acceptable evidence. In lieu of the label or listing, a written certificate from an approved nationally recognized testing laboratory (NRTL) equipped to perform such services, stating that the items have been tested and conform to the requirements and testing methods of Underwriters Laboratories may be submitted.

1.6.5.1 Alternative Qualifications

Products having less than a 2-year field service record will be acceptable if the manufacturer has been regularly engaged in the design and production of solar photovoltaic products for a minimum of 5-years. Similar photovoltaic products must have been in satisfactory commercial or industrial use for 5-years prior to bid opening and must have been on sale on the commercial market through advertisements, manufacturers' catalogs, or brochures during the 5-year period.

1.6.5.2 Material and Equipment Manufacturing Date

Products manufactured more than 1-year prior to date of delivery to site must not be used, unless specified otherwise.

1.6.6 Cybersecurity Equipment Certification

****
NOTE: Coordinate equipment certification with Government's cybersecurity requirements and interpretations. Verify that the system includes remote control or remote access capability.
****

Furnish a certification that control systems are designed and tested in accordance with DoD Instruction 8500.01, DoD Instruction 8510.01, and as required by individual Service Implementation Policy.

1.6.7 Operation and Maintenance Data

Submit Solar Photovoltaic Systems data package for the following items in accordance with Section 01 78 23 OPERATION AND MAINTENANCE DATA.

a. Troubleshooting guide.

b. Warranty.

c. Operation instructions.

d. Preventive maintenance and inspection data, including a schedule for system operators.

****
NOTE: To aid in identifying locations of modules for troubleshooting, identify modules on as-built plans according to groups or zones.
****

[e. As-built plans displaying modules identified according groups or zones, coordinated with activity to organize as required.

]1.6.7.1 Electrical Systems

Submit operation and maintenance data in accordance with Section 01 78 23 OPERATION AND MAINTENANCE DATA. In addition to requirements of Data Package 5, include the following for the actual solar photovoltaic (PV) system provided:

a. Service and maintenance information including preventive maintenance, assembly, and disassembly procedures.

b. Complete operation, repair, and maintenance information, detailed to the smallest replaceable unit.

c. Adjustment, trouble-shooting, configuration, tuning, and system calibration instructions.

d. Programming information for the communications and monitoring interface.

e. An instruction manual with pertinent items and information highlighted.

f. A layout drawing showing locations as well as views of equipment; front, top, and side views.

g. A one-line drawing showing all components and interfaces to the electrical system.

h. Prices for spare parts and supply list.

i. Inverter efficiency report and field acceptance test reports.

j. Actual nameplate diagram.

k. Date of purchase.

1.6.7.2 Training Course

The proposed Training Course Curriculum (including topics and dates of discussion) indicating that all of the items contained in the operating and maintenance instructions, as well as demonstrations of safety and routine maintenance operations, including testing procedures included in the maintenance instructions, are to be covered. The proposed Training Course must be video-recorded and provided with any PowerPoint slides as part of the final documentation for those that cannot attend. Safety training must be extended to fire department representatives.

1.6.8 Bill of Materials

Submit a Bill of Materials listing each product being incorporated into the system. Bill of Materials includes a general description of the product, quantity, and exact manufacturer's model number. Where the manufacturer's model number does not fully identify the product, list options, accessories, or custom features by additional descriptions.

1.6.9 Qualified Testing Organization

Comply with requirements specified in Section 26 08 00 APPARATUS INSPECTION AND TESTING. Engage the services of a qualified testing organization, NABCEP-certified professional, or licensed electrician to provide inspection, testing, calibration, and adjustment of the solar photovoltaic electrical distribution system and equipment listed herein. Organization must be independent of the supplier, manufacturer, and installer of the equipment. The organization must be a first tier contractor.

Submit name and qualifications of organization. Organization must have been regularly engaged in the testing of electrical materials, devices, installations, and regularly engaged in solar PV systems for a minimum of five years.

Organization calibration program requirements:

a. Provide a calibration program which assures that all applicable test instruments are maintained within rated accuracy.

b. Accuracy: Traceable to the National Institute of Standards and Technology.

c. Instrument calibration frequency schedule: Less than or equal to 12 months for both test floor instruments and leased specialty equipment.

d. Dated calibration tables: Visible on all test equipment.

e. Calibrating standard: Higher accuracy than that of the instrument tested.

f. Keep up-to-date records that indicate dates and test results of instruments calibrated or tested. For instruments calibrated by the manufacturer on a routine basis, in lieu of third party calibration, include the following:

(1) Maintain up-to-date instrument calibration instructions and procedures for each test instrument.

(2) Identify the third party laboratory calibrated instrument to verify that calibrating standard is met.

1.6.10 System Performance Calculations

Submit system performance calculations to show that the components provided will produce the minimum required production of power in accordance with PERFORMANCE REQUIREMENTS paragraph.

1.7 DELIVERY, STORAGE, AND HANDLING

a. Store solar PV modules in their original packaging according to the manufacturer's guidance, and do not remove from packaging until day of installation.

b. If a solar PV module is removed from its packaging, store it according to the manufacturer's guidance.

c. Do not store solar PV modules on-site for more than 12 months.

1.8 WARRANTY

****
NOTE: Option to provide spare modules and inverters is prohibited for the Navy, and do not provide for other Services without specific authority of Contracting Officer.
****

****
NOTE: Generally PV module degradation data is not readily available from the manufacturer. Environmental factors can significantly influence degradation. Long-term field degradation studies indicate 0.5-0.8 percent for monocrystalline and polycrystalline modules. Degradation is higher for thin-film modules at 0.7-1.0 percent. New PV module designs generally have improved degradation rates.
****

The equipment items must be supported by service organizations which are reasonably convenient to the equipment installation in order to render

satisfactory service to the equipment on a regular and emergency basis during the warranty period of the contract.

1.8.1 Solar Photovoltaic Modules

Furnish the solar photovoltaic module manufacturer's warranty. The warranty must be a 25-year linear 80 percent (minimum) power warranty (at the end of the 25th year after purchase an actual minimum power output of 80 percent based on the nameplate rating must be achieved) and not less than 10-years for workmanship material and manufacturing defects from the date of manufacture.

The warranty must state that the malfunctioning solar photovoltaic module must be exchanged by the manufacturer and promptly shipped to the using Government facility. The replacement solar module must be identical to, or an improvement upon, the original design of the malfunctioning solar module. [Provide an extra [_____] percent of spare modules in the event of necessary replacement of malfunctioning installed module.]

1.8.2 Inverters

Furnish the inverter manufacturer's warranty. The warranty period must be 15 years (minimum) from the date of manufacture. Inverter device installation, transportation, and on-site storage must not exceed 12 months, thereby permitting 14 years of the 15 year warranty to be in service and energized.

The warranty must state that the malfunctioning inverter must be exchanged by the manufacturer and promptly shipped to the using Government facility, and arrive in no more than ten days. The replacement inverter must be identical to, or an improvement upon, the original design of the malfunctioning inverter. [Provide an extra [_____] percent of spare inverters in the event of necessary replacement of malfunctioning installed inverter.]

1.9 CALCULATIONS

If construction deviates from design, provide relevant calculations to demonstrate that new design is satisfactory and approved by a licensed professional engineer.

1.10 HEALTH AND SAFETY RECOMMENDATIONS

Section 01 35 26 GOVERNMENTAL SAFETY REQUIREMENTS, applies to this section with additions and modifications specified herein.

PART 2 PRODUCTS

2.1 SYSTEM DESCRIPTION

****
NOTE: System voltage greater than 1,000 VDC requires a waiver due to limitations in UFC 3-440-01 FACILITY-SCALE RENEWABLE ENERGY SYSTEMS and this UFGS.
****

a. The PV system described in this document is of the grid-connected type and does not include battery/backup storage or secondary electrical

generation devices. PV system feeds AC power into the local services when solar energy is available and immediately disconnects from the grid upon loss of grid power to the service in accordance with IEEE 1547and local utility regulations.

b. PV system must comply with these specifications, all applicable construction document drawings, all applicable codes, and all local authorities having jurisdiction. System must comply with all policies and standards required by the electrical utility having jurisdiction and all applicable incentive program guidelines. PV system equipment includes, but is not limited to, PV modules and electrical insulating components such as encapsulants and backsheets, raceways, inverters, combiner boxes, disconnect switches, wire, conduit, junction boxes, mounting hardware, monitoring and communication equipment.

****
NOTE: Applies if PV array is roof-mounted.
****

[c. Coordinate with roofing to provide certificate of roof warranty not invalidated by solar PV installation. For rigid solar cell PV systems on metal roofing panels, integrate with the roofing system, Section 07 60 00 FLASHING AND SHEET METAL.]

****
NOTE: Applies if lightning protection system is required.
****

[d. Provide lightning arrestor listed to UL 1449.

]2.1.1 System Requirements

Conform electrical installations to IEEE C2, NFPA 70, and requirements specified herein.

****
NOTE: Input values generated from a solar PV computer program such as the System Advisor Model (SAM) computer program or PVWatts or from data supplemented by multiple programs. If another mounting structure is provided, the project documents must fully describe it.
****

a. Solar photovoltaic system characteristics provided includes:

(1) [_____] minimum rated kW DC output

(2) [_____] minimum rated kW AC output

(3) [_____] minimum kWh AC per year for year one

(4) [_____] system voltage

(5) [Ground][Roof][_____] mounted.

b. All equipment must be listed and labeled in accordance with OSHA-listed nationally recognized testing laboratories (NRTL) and

installed in accordance with the listing requirements and the manufacturer's instructions.

c. Provide all accessories needed for a complete, secure, operational grid-tied PV system.

d. Wiring and connections of inverters, PV source circuits, AC branch circuits, and all interconnections must be rated at a minimum for IP65 in accordance with NEMA IEC 60529.

2.1.2 Performance Requirements

****
NOTE: ASHRAE 189.1 requires an annual renewable energy production requirement of no less than 20 kWh/m^2 6.0 kBtu/ft^2 multiplied by total roof area for single-story buildings, and not less than 32 kWh/m^2 10 kBtu/ft^2 multiplied by total roof area for all other buildings, over the life of the system. This result refers to the rated DC nameplate capacity of the system.
****

System components provided must be selected to achieve a minimum calculated energy production of [_____] kWh per year as required by ASHRAE 189.1.

2.2 PHOTOVOLTAIC MODULES

****
NOTE: For crystalline-silicon modules, manufacturer must submit a Letter of Conformance to certify the consistency and quality of materials used.

TO DOWNLOAD LETTER OF CONFORMANCE

Go to:
http://www.wbdg.org/ffc/dod/unified-facilities-guide-specifications-ufgs/for
****

****
NOTE: IEC 61215 applies to crystalline-silicon modules and IEC 61646 applies to thin-film modules. Use UL 1703 applies to domestic projects and IEC 61730 applies to international projects.
****

a. PV modules must be [IEC 61215] [IEC 61646] compliant and [IEC 61730-1 compliant] [listed to UL 1703], and manufactured in an ISO 9001 certified facility.

****
NOTE: Select commercially-available solar PV module technology that meets the requirements in this UFGS and with the guidance from UFC 3-440-01 FACILITY-SCALE RENEWABLE ENERGY SYSTEMS. Warning: Currently, only monocrystalline and polycrystalline can meet energy density requirements. If building-integrated PV (BIPV) is the chosen

technology, there must be at least three manufacturers that offer a viable product. If thin-film is the chosen technology, there must be at last three manufacturers that can be of different thin-film technologies.

****

[b. PV modules must be of [monocrystalline][polycrystalline]technology and

(1) [for rack-mounting.]

(2) [BIPV.]

][c. PV modules must be of thin-film technology and

(1) [for rack-mounting.]

(2) [amorphous.]

(3) [BIPV.]]

****

NOTE: Select efficiency appropriate to solar PV module technology. If selected technology is not given below, designer of record must have module efficiency measurement verified by a nationally-recognized testing laboratory (NRTL) under standard test conditions (STC): Irradiance of 1,000 W/m^2, solar spectrum of air mass (AM) 1.5, and module temperature of 25 degrees C 77 degrees F.

****

d. PV module efficiency must be greater than [15 percent for crystalline] [13 percent for thin film] [10 percent for amorphous and BIPV] [_____] technology.

e. PV modules must be of the same manufacturer and model number and consistent sub-components.

f. Submit on cutsheets PV module performance data from the manufacturer that must include a flash test data in accordance with IEC 61853-1, and temperature coefficients at: STC, nominal operating cell temperature (NOCT), low irradiance conditions (LIC), high temperature conditions (HTC), and low temperature conditions (LTC).

****

NOTE: Solar PV modules with single conductor output cables are commonly available. Conduit-ready junction boxes are only necessary in hazardous locations.

****

g. PV module bypass diodes must be inside the solar PV module's [conduit-ready] [single conductor cable] junction box.

****

NOTE: UL 6703 standard for multi-pole connectors for use in photovoltaic systems is in development.

Once it is applicable, add to this UFGS.
****

h. Photovoltaic wire, wiring methods, and utilization of locking-type connectors must comply with the requirements of NFPA 70. Provide USE-2 or RHH or RHW-2 wire, and sunlight-resistant wire when exposed to sunlight.

2.2.1 Crystalline Photovoltaic Module Backsheet

a. Backsheet component must consist of a tri-layer construction (minimum thickness of 250 microns 9.8 mils) with outer layers of polyvinyl fluoride (PVF) and an inner layer of polyester for crystalline-silicon modules with a maximum system voltage of 1000 VDC.

b. Alternate polymeric backsheets consisting of different chemical composition, thickness, or construction must fulfill the safety and performance specifications and acceptance criteria in Table 1. The required component properties in Table 1 must be verified by a test report provided by an OSHA-listed nationally recognized testing laboratory (NRTL) and a cutsheet submitted.

TABLE 1 - PV MODULE BACKSHEET COMPONENT SAFETY AND PERFORMANCE

Items	Test Methods	Specification
Tensile Strength (MPa)	ASTM D882	>=100 (TD) >=100 (MD)
Elongation at Break (percent)	ASTM D882	>=80 (TD) >=100 (MD)
Dimensional Stability (percent, 150 degrees C, 0.5 h)	ASTM D882	<=1.0 (TD) <=1.0 (MD)
Breakdown Voltage (kV)	ASTM D149	>=18
WVTR (g/m^2 day, 37.8 degrees C, 100 percent RH)	ASTM F1249	<=2.5
Interlayer Peeling Strength (N/cm)	ASTM D1876	>=4
Peeling Strength with EVA (N/cm)	ASTM D903	>=40
Damp Heat (85 degrees C, 85 percent RH, 1000 hrs) -Color Change delta b -Elongation Retention (percent) -Appearance	ASTM E1171 ASTM E308/ASTM D2244 ASTM D882/ASTM D5870	<=2.5 >=70 No cracking or delamination.

TABLE 1 - PV MODULE BACKSHEET COMPONENT SAFETY AND PERFORMANCE		
UV Exposure Irradiance of 0.55 W/m^2 at 340 nm (61 W/m^2) using a xenon lamp with a daylight filter (outer layer). Exposure is 4200 hours (260 kWh/m^2 total UV (300-400 nm)) -Color Change delta b -Elongation Retention (percent) -Tensile Retention (percent) -Appearance	ASTM G155 ASTM E308/ASTM D2244 ASTM D882/ASTM D5870 ASTM D882/ASTM D5870	<=2.0 >=70 >=70 No cracking or delamination.

2.2.2 Crystalline Photovoltaic Module Encapsulent

a. Encapsulant component must consist of ethyl vinyl acetate (EVA) with a total nominal (prelamination) thickness of 900 microns 35 mils or greater in the completed module. The EVA must have a minimum of 28 percent VA content. Through statistical process control, the module manufacturer must ensure that the cured EVA has a minimum of 70 percent gel content per ASTM D7567 or ASTM D2765. The EVA must have a UV cutoff wavelength of 360 nm as measured according to ASTM E424. The EVA must have a minimum volume resistivity of 1X10^15 ohm-cm per ASTM D257.

b. Thermoplastic encapsulants consisting of different chemical composition, thickness, or construction must fulfill the safety and performance specifications and acceptance criteria described in Table 2. The required component properties described in Table 2 must be verified by a test report provided by an OSHA-listed nationally recognized testing laboratory (NRTL) and a cutsheet submitted.

TABLE 2 - PV MODULE ENCAPSULANT COMPONENT PROPERTIES		
Items	Test Methods	Specification
Appearance	Visual Examination	No bubble, crack, or delamination.
Gel Content (percent)	ASTM D7567/ASTM D2765	>=70
UV Cutoff Wavelength (nm)	ASTM E424	>=360
Volume Resistivity (ohm-cm)	ASTM D257	>=1X10^15

2.3 INVERTERS

a. Array-to-inverter kW ratio must not exceed manufacturer recommendations. Inverter must be IEEE 1547 compliant, listed to UL 1741, comply with the latest applicable ANSI and FCC standards and

addenda, and inspected before commissioning, testing, and operation of the system. Submit documentation validating system performance requirements.

b. Inverter must be approved by FCC Part 15, Class A as an unintentional radiator.

c. All same-sized inverters supplied must be of the same manufacturer and model number.

****
NOTE: Select the inverter mounting system appropriate for the project environment. Select support structure mount or module attached for microinverters..
****

d. Provide inverter utilizing a [floor-mount][wall-mount][support structure mount][module attached] system..

****
NOTE: Select the NEMA enclosure and enclosure material appropriate for the project environment.
****

e. Provide inverter utilizing a [NEMA 6/6P outdoor for coastal environments][NEMA 3R outdoor][NEMA 1 indoor]enclosure in accordance with NEMA 250. Provide enclosure made of [steel][aluminum][stainless steel].

f. Provide inverter with anti-islanding protection to prevent back-feeding inverter generated power to the grid in the event of a utility outage. Anti-islanding protection must be listed to UL 1741 and IEEE 1547.

g. Overcurrent protection, ground fault protection, arc fault circuit interrupter (AFCI), and rapid shutdown must comply with the requirements of NFPA 70.

h. Provide inverter with self-diagnostics routines, and remote and local display of operating status and remote monitoring capabilities. Provide inverter compatible with monitoring system and metering system. If capability for remote monitoring and control does not exist, then it must be added.

****
NOTE: Consider implementing an inverter with integrated monitoring system if design allows, for better safety, and operations and maintenance. Most microinverters have this feature as well as some source circuit inverters.
****

[i. Provide inverter with integrated monitoring system.

] j. Rate inverter output as [_____] AC kW at unity (1), [_____] phase, [_____] volts, [_____] MPPT voltage range.

k. Match inverter DC input to the design of the PV module array outputs

and account for the following:

(1) The inverter low voltage is 50 percent of the maximum system voltage, to account for 25 year degradation.

(2) Voltage decrease due to high temperatures at project site.

****
NOTE: If inverters are provided without transformers built-in, provide an isolation transformer to serve multiple inverters for the PV system. Isolation transformer is necessary to isolate inverter AC components from entering the grid. Many utilities do not allow inverters without isolation.
****

l. Provide isolation transformer via [built into each inverter][system central transformer for multiple inverters] to provide safe galvanic separation between the AC side of the inverter and the grid.

****
NOTE: String inverter with integral AC and DC disconnecting means is optional. Disconnecting means may be internal or external to the inverter. Integral disconnecting means is not an option for microinverters.
****

m. [Inverter must include AC and DC disconnecting means. DC and AC disconnecting means must be listed with ratings suitable for the intended use and purpose.] System disconnecting means must meet the requirements of NFPA 70.

2.3.1 String Inverters

****
NOTE: String inverters sized greater than 600kW and DC-optimized string inverters of any size must have an efficiency of at least 98 percent. Conventional and smaller string inverters must have an efficiency of at least 96 percent.
****

****
NOTE: The California Energy Commission (CEC) weighted average inverter power conversion efficiency is a standardized method. Inverter efficiencies are updated on the CEC web site http://www.gosolarcalifornia.ca.gov/equipment/inverters.php
****

a. Submit String Inverter CEC Efficiency as verified by CEC SAND2007-5036 of having a weighted average inverter power conversion efficiency of [98 percent][96 percent][93 percent with external isolation transformer] or greater.

b. Allow the use of DC optimizers provided that a design which coordinates the DC optimizers and the inverter(s) is approved by the

Contracting Officer.

****
NOTE: Apply if string inverter does not use DC power optimizer. DC power optimizer provides MPPT.
****

[c. Inverter must feature maximum power point tracking (MPPT).

]2.3.2 Micro Inverters

****
NOTE: Micro-inverters may be provided preattached to each solar PV module, or may be installed on the racking or mounting system.
****

a. Provide microinverters [mounted on racking or mounting system by the installer][preinstalled on each solar PV module], and comply with applicable requirements in article INVERTERS.

****
NOTE: The California Energy Commission (CEC) weighted average inverter power conversion efficiency is a standardized method. Inverter efficiencies are updated on the CEC web site http://www.gosolarcalifornia.ca.gov/equipment/inverters.php
****

b. Submit Microinverter CEC Efficiency as verified by CEC SAND2007-5036 of having a weighted average inverter power conversion efficiency of 96 percent or greater.

c. Inverter must feature maximum power point tracking (MPPT).

2.4 COMBINER BOXES

****
NOTE: If photovoltaic system size becomes sufficiently large, refer to Section 48 14 00 SOLAR PHOTOVOLTAIC SYSTEMS - UTILITY.
****

a. All combiner boxes must be listed to UL 1741, and inspected before commissioning, testing, and operation of the system.

b. Provide combiner boxes [in wall-mount][support structure mount], [NEMA 6/6P outdoor for coastal environments][NEMA 4/4X outdoor][NEMA 3R outdoor] [steel][aluminum][stainless steel][polymeric] enclosures in accordance with NEMA 250.

c. Supply combiner boxes designed for use with the inverter provided, and coordinated to the specific PV source circuit design.

d. Provide combiner boxes of compact design with simplified input and output wiring.

e. Provide overcurrent protection and output disconnecting means that comply with the requirements of NFPA 70.

[2.5 ROOF MOUNTING STRUCTURE FOR MODULES (RACKING)

****
NOTE: Delete paragraph if the project does not utilize a roof mounting structure.
****

****
NOTE: Coordinate with licensed professional engineer for the design of the mounting structure details and connection to existing building. Racking layout may include a gap between continuous rows of modules to allow for ventilation.

Coordinate with the Activity and determine if tracking is desired and ensure they understand the unique additional maintenance requirements involved. Refer to UFC 3-440-01 FACILITY-SCALE RENEWABLE ENERGY SYSTEMS for additional information.
****

a. Provide racking [with [single-axis][dual-axis] tracking] for array as indicated on the drawings, including the module azimuth and tilt [for each inverter's separate array].[See paragraph entitled PV TRACKING SYSTEM for tracking requirements.] Provide racking compliant with UL 2703.

****
NOTE: Indicate snow load and wind load requirements as applicable for the location and building occupancy category in accordance with UFC 3-301-01, ASCE 7-16 and IBC modifications in UFC 1-200-01.
****

b. Racking and PV array, including modules, hardware, and attachments, must withstand [snow loads and] wind loads as required by ASCE 7-16 and ICC IBC.

****
NOTE: Defer to local code where applicable, UFC 3-301-01, ASCE 7-16 and IBC modifications in UFC 1-200-01. Otherwise the structure's Seismic Design Category is based on the risk category of the structure, long and short period mapped acceleration parameters for the area, and site class based on soil conditions.
****

c. Racking must be suitable for Seismic Design Category [_____] as defined by ASCE 7-16 and ICC IBC.

d. Submit seismic and wind [and snow] load design calculations for the array mounting system and its attachment to the structure showing compliance with seismic and wind [and snow] requirements while supporting the PV modules.

e. Provide the mechanical hardware for mounting the PV arrays and all other hardware required for assembling the PV modules, and the

attachments to the building structure.

****
NOTE: In hostile environments, the additional cost of stainless steel components may be justified. Manufacturer's standard construction material is acceptable only in noncoastal and noncorrosive environments. Choose bracketed option for hostile environments. All fasteners for PV module aluminum frames must be stainless steel. Galvanized fasteners must not contact aluminum PV module frames or racking. Coordinate with structural engineer and geotechnical report.
****

f. Use array mounting hardware compatible with the site considerations and environment. [Select mechanical hardware for corrosion resistance and durability.]Use a stainless steel, galvanized steel, or aluminum support structure. Do not use wood or plastic components for support.

****
NOTE: Choose bracketed option for corrosive soil. Coordinate with structural engineer and geotechnical report.
****

g. Use cathodic protection compatible with the site considerations and environment. Utilize galvanized anchor [encased in concrete] driven into ground.

2.5.1 Mounting System Base Supports

Fabricate with fastening points integral to the mounting structure. Mounting system supports must be permanently affixed stanchions that are anchored to the building structure. Coordinate height with thickness of roof insulation.

2.5.2 Flashing Boot

Fabricate for precision fit over base support. Coordinate height with base supports.

2.5.3 Base Cap

Fabricate to overlap base support and flashing boot a minimum of 51 mm 2 inches.

2.5.4 Base Cap Gasket

EPDM with self-adhesive closed cell foam or other gasketing material compatible with the roofing material.

2.5.5 Framing

Provide with wall thickness as determined by structural calculations.

2.5.6 Hardware

Bolts, nuts, washers, and screws must be 18-8 stainless steel.

][2.6 GROUND MOUNTING STRUCTURE FOR MODULES

****
NOTE: Delete paragraph if the project does not utilize a ground mounting structure.
****

****
NOTE: Coordinate with licensed professional engineer for the design of the mounting structure details and connection to existing building. For tracking array design, refer to UFC 3-440-01 FACILITY-SCALE RENEWABLE ENERGY SYSTEMS and coordinate with Activity.
****

a. Provide racking [with [single-axis] [dual-axis] tracking] for array as indicated on the drawings, including the module azimuth and tilt [for each inverter's separate array].[See paragraph entitled PV TRACKING SYSTEM for tracking requirements.] Provide racking compliant with UL 2703.

****
NOTE: Indicate snow load and wind load requirements as applicable for the location and building occupancy category in accordance with UFC 3-301-01, ASCE 7-16 and IBC modifications in UFC 1-200-01.
****

b. Racking and PV array, including modules, hardware, and attachments, must withstand [snow loads and] wind loads as required by ASCE 7-16 and ICC IBC.

****
NOTE: Defer to local code where applicable, UFC 3-301-01, ASCE 7-16 and IBC modifications in UFC 1-200-01. Otherwise the structure's Seismic Design Category is based on the risk category of the structure, long and short period mapped acceleration parameters for the area, and site class based on soil conditions.
****

c. Racking must be suitable for Seismic Design Category [_____] as defined by ASCE 7-16 and ICC IBC.

d. Submit seismic and wind [and snow] load design calculations for the array mounting system and its attachment to the structure showing compliance with seismic and wind [and snow] requirements while supporting the PV modules.

e. Provide the mechanical hardware for mounting the PV arrays and all other hardware required for assembling the PV modules, and the attachments to the mounting structure.

****
NOTE: In hostile environments, the additional cost of stainless steel components may be justified.

Manufacturer's standard construction material is acceptable only in noncoastal and noncorrosive environments. Choose bracketed option for hostile environments. All fasteners for PV module aluminum frames must be stainless steel. Galvanized fasteners must not contact aluminum PV module frames or racking. Coordinate with structural engineer and geotechnical report.

****

f. Use array mounting hardware compatible with the site considerations and environment. [Select mechanical hardware for corrosion resistance and durability.]Use a stainless steel, galvanized steel, or aluminum support structure. Do not use wood or plastic components for support.

****

NOTE: Choose bracketed option for corrosive soil. Coordinate with structural engineer and geotechnical report.

****

g. Use cathodic protection compatible with the site considerations and environment. Utilize galvanized anchor [encased in concrete] driven into ground.

[2.6.1 Driven Pile

****

NOTE: For appropriate pile type, coordinate with structural engineer and geotechnical report.

****

Provide driven pile as indicated in accordance with PDCA Specification 103.

][2.6.2 Helical Pile

****

NOTE: For appropriate pile type, coordinate with structural engineer and geotechnical report.

****

Provide helical pile as indicated in accordance with ICC IBC.

]][2.7 CAST-IN-PLACE CONCRETE

****

NOTE: Use the first bracketed paragraph when project includes a concrete section in Division 03; otherwise, the second bracketed paragraph may be used. Coordinate requirements with Section 03 30 00 CAST-IN-PLACE CONCRETE. Coordinate with structural engineer and geotechnical report.

****

[Provide concrete associated with electrical work for other than encasement of underground ducts rated for 30 MPa 4000 psi minimum 28-day compressive strength unless specified otherwise. Conform to the requirements of Section 03 30 00 CAST-IN-PLACE CONCRETE.]

****

NOTE: If concrete requirements are detailed and no cast-in-place section is to be included in the project specification, refer to Section 03 30 00 CAST-IN-PLACE CONCRETE and select such portions as needed to provide complete requirements in addition to the requirements below.

****

[Provide concrete associated with electrical work as follows:

a. Composed of fine aggregate, coarse aggregate, Portland cement, and water so proportioned and mixed as to produce a plastic, workable mixture.

b. Fine aggregate: hard, dense, durable, clean, and uncoated sand.

c. Coarse aggregate: reasonably well graded from 4.75 mm to 25 mm 3/16 inch to 1 inch.

d. Fine and coarse aggregates: free from injurious amounts of dirt, vegetable matter, soft fragments or other deleterious substances.

e. Water: fresh, clean, and free from salts, alkali, organic matter, and other impurities.

f. Concrete associated with electrical work for other than encasement of underground ducts: 30 MPa 4000 psi minimum 28-day compressive strength unless specified otherwise.

g. Slump: Less than 100 mm 4 inches. Retempering of concrete will not be permitted.

h. Exposed, unformed concrete surfaces: smooth, wood float finish.

i. Concrete must be cured for a period of not less than 7 days, and concrete made with high early strength Portland cement must be repaired by patching honeycombed or otherwise defective areas with cement mortar as directed by the Contracting Officer.

j. Air entrain concrete exposed to weather using an air-entraining admixture conforming to ASTM C260/C260M.

k. Air content: between 4 and 6 percent.

]2.7.1 Foundation Anchorage

Anchor mounting structure to concrete pad in accordance with Section 05 12 00 STRUCTURAL STEEL.

][2.8 PV TRACKING SYSTEM

****

NOTE: For tracking array design, refer to UFC 3-440-01, FACILITY-SCALE RENEWABLE ENERGY SYSTEMS and coordinate with Activity.

****

Provide PV tracking system in accordance with IEC TS 62727.

]2.9 PV SYSTEM MONITORING

a. Provide a PV system monitoring panel mounted as indicated.

****
NOTE: Select display option(s) as indicated. Bracketed attributes are optional. Select attribute's source based on use of micro-inverters or string-inverters.
****

b. The following quantities must be viewable [from a [remote][local] [touch]screen display mounted at location as indicated]:

(1) DC Input Voltage from PV [array][modules]

[(2) DC Input Power from PV [system][module]

] (3) DC Input Current from PV [system][module]

(4) AC Phase Current from [inverter][PV system] (average)

(5) AC Voltage from [inverter][PV system] (average)

(6) AC Real Power from [inverter][PV system]

(7) Daily, Weekly, Monthly, Yearly, and Cumulative Energy Production

(8) Fault Status Report

(9) DC Ground Current Report

(10) AC Neutral Current from [inverter][PV system]

[(11) AC Reactive Power from [inverter][PV system]

][(12) AC Apparent Power from [inverter]

] (13) AC Power Factor

[(14) AC Phase Current from inverter (A, B, C)

][(15) AC Voltage from inverter (A, B, C)

][(16) AC Voltage and Current Balance.]

****
NOTE: Select data acquisition sensors as indicated. Irradiance measures amount of sunlight available. Wind speed, ambient temperature, and PV module temperature can affect performance.
****

c. Provide additional data acquisition sensors to measure [irradiance] [wind speed] [ambient temperature] [PV module temperature]. Any additional data acquisition sensors require a conduit separate from the current conductor conduit.

2.10 PV SYSTEM METERING

****

NOTE: Navy projects require the use of Section 26 27 14.00 20 ELECTRICITY METERING. Air Force projects may require the use of Section 26 27 13.10 30 ELECTRIC METERS. Army projects refer to Section 26 12 21 SINGLE-PHASE PAD-MOUNTED TRANSFORMERS.

Use a revenue-grade meter if excess power will be sent back to the utility, otherwise use a non-revenue-grade meter.

****

a. Comply with metering requirements in [Section 26 27 14.00 20 ELECTRICITY METERING] [Section 26 27 13.10 30 ELECTRIC METERS] [Section 26 12 21 SINGLE-PHASE PAD-MOUNTED TRANSFORMERS].

b. Provide a [revenue-grade][non-revenue-grade] Interval Data Recording (IDR) meter complete with industry standard telemetry for communications with Ethernet, cellular, or other common output capabilities. Conform to CSI requirements and electrical utility requirements.

c. Connect to a monitoring/data collection recording solar production through time increments applicable to installation and utility standards, with a minimum of 15-minute intervals and 30-day memory.

d. UL listed and conform to ANSI C12.1.

e. Measure kWh, demand, instantaneous power, volts, amps, and watts.

f. Provide UL listed communication and annunciator panel.

2.11 POSTED OPERATING INSTRUCTIONS

Provide for each system and principal item of equipment as specified in the technical sections for use by the operation and maintenance personnel. The operating instructions include the following:

a. Wiring diagrams, schematic diagrams, interconnection diagrams, control diagrams, and control sequence for each principal system and item of equipment.

b. Array layout showing the locations of all DC and AC disconnects.

c. Start up, proper adjustment, operating, and shutdown procedures.

d. Safety precautions.

e. The procedure in the event of equipment failure.

f. Other items of instruction as recommended by the manufacturer of each system or item of equipment.

Print operating instructions and frame under glass or in approved laminated plastic. Post instructions where directed. For operating instructions exposed to the weather, provide weather-resistant materials

or weatherproof enclosures. Operating instructions do not fade when exposed to sunlight and secure to prevent easy removal or peeling.

2.12 MANUFACTURER'S NAMEPLATE

Each item of equipment must have a nameplate bearing the manufacturer's name, address, model number, and serial number securely affixed in a conspicuous place; the nameplate of the distributing agent will not be acceptable. For PV modules, a label on the back of the module is acceptable.

2.13 FIELD FABRICATED NAMEPLATES

****
NOTE: Use the following paragraph where nameplates are fabricated to identify specific equipment designated on the drawings.
****

ASTM D709. Provide laminated plastic nameplates for each equipment enclosure, relay, switch, and device; as specified. Each nameplate inscription identifies the function and, when applicable, the position. Nameplates are of melamine plastic, 3.175 mm 0.125 inch thick, white with black center core. Surface is of matte finish. Square corners. Accurately align lettering and engrave into the core. Minimum size of nameplates is 25.4 mm by 63.5 mm 1 inch by 2.5 inches. Lettering is a minimum of 6.35 mm 0.25 inch high normal block style.

2.14 PV EQUIPMENT MARKING AND WARNING LABELS

Provide warning signs for the enclosures of electrical equipment having a nominal rating exceeding 600 volts.

a. Provide PV equipment with UL 969 weather-resistant marking and warning labels in compliance with NFPA 1 and NFPA 70.

[b. When such equipment is guarded by a fence, mount signs on the fence. Provide metal signs having nominal dimensions of 355 mm by 255 mm 14 inches by 10 inches with the legend "DANGER HIGH VOLTAGE KEEP OUT" printed in three lines of nominal 75 mm 3 inches high white letters on a red and black field.

]2.15 CABLE TAGS IN MANHOLES, HANDHOLES, AND VAULTS

****
NOTE: Verify cable labeling requirements with the local Activity. Provide lead cable tags only when specifically required by the Activity.
****

Provide tags for each power cable or wire located in manholes, handholes, and vaults. The tags must be polyethylene[or sheet lead]. Do not provide handwritten letters. [The first position on the power cable tag must denote the voltage. The second through [sixth] [_____] positions on the tag must identify the circuit. [The next to last position must denote the phase of the circuit and must include the Greek "phi" symbol.] The last position must denote the cable size.] [Tag legend must be as indicated.]

2.16 GROUNDING AND BONDING

a. Provide properly sized equipment grounding conductors.

b. Provide bonding fittings on concentric/eccentric knockouts with metal conduits for circuits over 250 volts in accordance with NFPA 70.

c. Provide bonding fittings for ferrous metal conduits enclosing grounding electrode conductors in accordance with NFPA 70.

d. Provide grounding lugs for aluminum PV solar module frames of either stainless steel or tin-coated copper.

PART 3 EXECUTION

3.1 INSTALLATION INSTRUCTIONS AND INSTALLATION DRAWINGS

a. Complete all electrical work in accordance with NFPA 70.

b. Provide all permanent and temporary shoring, anchoring, and bracing required by the nature of this work in order to make all parts absolutely stable and rigid, even when such shoring, anchoring, and bracing are not explicitly called for.

c. Install the solar PV system in accordance with this section, installation drawings, and the printed installation instructions of the manufacturer.

d. Follow the manufacturer's installation recommendations to ensure no electricity is being fed to the grid and that all available disconnects are in the open position and fuses are not installed during wiring operations. 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 must have direct current ground fault protection in accordance with NFPA 70. Ensure breakers in combiner box are in the off position (or fuses removed) during combiner box wiring.

e. Attach solar PV modules to the mounting structure according to the manufacturer's instructions and approved plans.

f. Install instrumentation according to the manufacturer's instructions, with control panels located as indicated.

3.1.1 Wiring Methods

Install wiring in accordance with NFPA 70 and Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM.

3.1.2 Electrical Connections

a. Use twist on wire connectors listed for the environment (i.e. wet, damp, direct burial) and installed per manufacturer's instructions.

b. Use listed power distribution blocks.

c. Use terminals containing more than one conductor listed for multiple conductors.

d. Use connectors and terminals used for fine strand conductors that are listed for use with such conductors.

e. Utilize appropriate tools for connector type as recommended by the manufacturer.

f. Tighten and secure module connectors.

g. Provide corrosion protection in accordance with Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM, and by adding a stainless steel isolating washer between components of incompatible metals on the racking structure.

3.1.3 Disconnects

a. Install disconnects for all current carrying conductors of the PV source.

b. Install disconnects for the PV equipment. For inverters and other equipment that are energized from more than one source, group and identify the disconnecting means.

c. Install disconnects and overcurrent protection for all ungrounded conductors in ungrounded (transformerless) PV power systems.

3.1.4 Overcurrent Protection

a. Install the PV interconnect overcurrent protective device as indicated in accordance with NFPA 70.

b. Install lightning arrestor as indicated and in accordance with NFPA 780.

3.1.5 Fire Safety

Firestop conduit that penetrates fire-rated walls, fire-rated partitions, or fire-rated floors in accordance with Section 07 84 00 FIRESTOPPING.

3.2 GROUNDING

3.2.1 PV System Grounding

****
NOTE: Racking manufacturers allow for different grounding schemes. Follow the racking manufacturer's grounding scheme.
****

NFPA 70 and IEEE C2, except provide grounding systems with a resistance to solid earth ground not exceeding [25] [_____] ohms. [Ground according to racking manufacturer's recommendations.]

Install grounding lugs in locations on the solar PV module as designated by the module manufacturer, using stainless steel machine screws of the thread size provided in the pre-tapped holes, along with a stainless steel star washer placed between the grounding lug and the solar module frame.

[3.2.2 Grounding Electrodes

****
NOTE: Include if grounding electrodes are provided.
****

Provide driven ground rods as specified in Section 33 71 02 UNDERGROUND ELECTRICAL DISTRIBUTION. Connect ground conductors to the upper end of ground rods by exothermic weld or compression connector. Provide compression connectors at equipment end of ground conductors.

]3.3 INSTALLATION OF EQUIPMENT AND ASSEMBLIES

3.3.1 Roof Mounted Structures

a. Ensure roof access points, paths, and clearances are as indicated.

b. The solar photovoltaic system details must be accepted by warranty roofing system manufacturer prior to installation. Upon completion of a rooftop system installation, obtain written certification that the rooftop warranty is still valid.

(1) For installation on a new roof, coordinate with roof manufacturer of new roof and obtain certificate.

(2) For installation on existing roof, coordinate with activity to provide certificate of continued validity of warranty from manufacturer.

c. Flash and counter-flash all roof penetrations in accordance with ICC IBC.

d. Provide a minimum 115 mm 4.5 inches air gap between the solar PV module frame and the roof surface.

e. Comply with requirements in NRCA 3767 for working with different roof types.

[3.3.2 Ground Mounted Structures

****
NOTE: Include if ground mounted structures are provided, and indicate appropriate foundation type.
****

[a. For concrete ballast or pad, install in accordance with Section 05 12 00 STRUCTURAL STEEL.

][b. For driven pile, install in accordance with PDCA Specification 103.

][c. For helical pile, install in accordance with ICC IBC.

]][3.3.3 Tracking Equipment

****
NOTE: Apply if tracking equipment is provided.
****

Install solar tracking equipment in accordance with IEC TS 62727.

]3.4 FIELD APPLIED PAINTING

Paint electrical equipment as required to match finish of adjacent surfaces or to meet the indicated or specified safety criteria. Painting must be as specified in Section 09 90 00 PAINTS AND COATINGS.

3.5 FIELD FABRICATED NAMEPLATE MOUNTING

Provide number, location, and letter designation of nameplates as indicated. Fasten nameplates to the device with a minimum of two sheet-metal screws or two rivets.

3.6 WARNING SIGN MOUNTING

a. Display calculated maximum and minimum voltages and their respective amperages on engraved warning labels.

b. Provide the number of signs required to be readable from each accessible side. Space the signs in accordance with NFPA 70E.

3.7 CABLE TAG INSTALLATION

Install cable tags in each manhole, handhole, and vault as specified, including each splice. [Tag only new wire and cable provided and existing wire and cable which are indicated to have splices and terminations provided.] Install cable tags over the fireproofing, if any, and locate the tags so that they are clearly visible without disturbing any cabling or wiring in the manholes, handholes, and vaults.

[3.8 FOUNDATION FOR EQUIPMENT AND ASSEMBLIES

****
NOTE: Provide if ground mounted system. Use the first bracketed option when project includes a concrete section in Division 03; otherwise, the second bracketed option (metric) or the third bracketed option (English) may be used.
****

Provide cast-in-place concrete work in accordance with the requirements of [Section 03 30 00 CAST-IN-PLACE CONCRETE][ACI 318M][ACI 318].

]3.9 FIELD QUALITY CONTROL

Perform in accordance with Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM.

3.9.1 Performance of NABCEP Acceptance Checks and Tests

Perform all inspections using a NABCEP-certified professional and in accordance with NABCEP inspection procedures, and in accordance with the manufacturer's recommendations, and include the following visual and mechanical inspections and electrical tests.

3.9.1.1 PV Modules

a. Visual and Mechanical Inspection

(1) Solar PV module manufacturer, model, and number of modules must

match the approved plans.

(2) Solar PV modules must be in good conditions (including but not limited to no broken glass or cells, no discoloration, frames not damaged).

b. Electrical Tests

(1) Verify output of PV modules according to manufacturer's recommendations and NABCEP practices.

3.9.1.2 Inverters

a. Visual and Mechanical Inspection

(1) Inverter manufacturer, model, and number of inverters must match the approved plans.

(2) Inverters must be in good condition.

b. Electrical Tests

(1) Verify output of inverters according to manufacturer's recommendations and NABCEP practices.

3.9.2 Performance of NETA Acceptance Checks and Tests

Perform in accordance with the manufacturer's recommendations, and include the following visual and mechanical inspections and electrical tests, performed in accordance with NETA ATS.

3.9.2.1 Grounding System

a. Visual and Mechanical Inspection

(1) Inspect ground system for compliance with contract plans and specifications.

b. Electrical Tests

(1) Perform ground-impedance measurements utilizing the fall-of-potential method. On systems consisting of interconnected ground rods, perform tests after interconnections are complete. On systems consisting of a single ground rod, perform tests before any wire is connected. Take measurements in normally dry weather, not less than 48 hours after rainfall. Use a portable ground resistance tester in accordance with manufacturer's instructions to test each ground or group of grounds. Use an instrument equipped with a meter reading directly in ohms or fractions thereof to indicate the ground value of the ground rod or grounding systems under test.

(2) Submit the measured ground resistance of each ground rod and grounding system, indicating the location of the rod and grounding system. Include the test method and test setup (i.e. pin location) used to determine ground resistance and soil conditions at the time the measurements were made.

3.9.3 Functional Acceptance Tests

a. Provide final and complete commissioning of the solar PV system in accordance with IEEE 1547.

b. Verify that all electrical components are installed and connected according to the requirements of the PV electrical drawings, specifications, and manufacturer's written instructions.

c. Before starting or operating the system, check continuity of all conductors and grounding conductors to verify that there are no faults and that all equipment has been properly installed according to the manufacturer's recommendations. Check factory instructions to see that installations have been made accordingly. Check equipment for any damage that may have occurred during shipment, after delivery, or during installation. Replace damaged equipment.

d. Before starting or operating the system, obtain a final inspection approval and final inspection from the Contracting Officer. Be present on site for both of these inspections.

e. Make final adjustments to all inverters and monitoring equipment so that they will be placed in an acceptable operating condition. Adjustable parameters must be set so that the PV system will produce the maximum possible amount of energy on an annual basis.

3.9.4 Cybersecurity Installation Certification

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NOTE: Coordinate equipment certification with Government's cybersecurity requirements and interpretations. Select this option if the solar photovoltaic system includes remote control or remote access capability.
****

Furnish a certification that control systems are installed in accordance with DoD Instruction 8500.01, DoD Instruction 8510.01, and as required by individual Service Implementation Policy.

3.10 CLOSEOUT ACTIVITIES

3.10.1 Demonstration

Upon completion of the work and at a time approved by the Contracting Officer, provide instructions by a qualified instructor to the Government personnel in the proper adjustment, system operation, and maintenance of the specified systems and equipment, including pertinent safety requirements as required. Government personnel must receive training comparable to the equipment manufacturer's factory training. Instructor must provide a separate training course for the monitoring system.

3.10.2 Instructor's Qualification Resume

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NOTE: Use the most appropriate and available option to provide the necessary training.
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Instructor(s) must be employee(s) of [installer] [manufacturer] [certified solar photovoltaic system training program]. Instructors must be thoroughly familiar with all parts of the installation and trained in operating theory as well as practical operation and maintenance work. Submit the name(s) and qualification resume(s) of instructor(s) to the Contracting Officer for approval.

3.10.3 Training Plan

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NOTE: Use the most appropriate hours to provide the necessary training. Video record instruction for absent and future employees.

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The training period must consist of a total of [2] [_____] hours of normal working time and begin after the system is functionally completed but prior to final acceptance tests. Submit the training course curriculum for approval, along with the proposed training date, at least 14 days prior to the date of proposed conduction of the training course. Instruction must be [video-recorded and] given during the first regular work week after the equipment or system has been accepted and turned over to the Government for regular operation. Provide [video recording and] any PowerPoint slides as part of the final documentation for those that cannot attend. Extend safety training to fire department representatives. Coordinate with Contracting Officer for Fire Department first responder training.

-- End of Section --