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USACE / NAVFAC / AFCEC **UFGS-26 31 00 (November 2021)**

Preparing Activity: NAVFAC **Superseding**
UFGS-26 31 00 (May 2015)

UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated July 2025
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SECTION TABLE OF CONTENTS

DIVISION 26 - ELECTRICAL

SECTION 26 31 00

FACILITY-SCALE SOLAR PHOTOVOLTAIC (PV) SYSTEMS

11/21

-- End of Section Table of Contents --

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SECTION 26 31 00

FACILITY-SCALE SOLAR PHOTOVOLTAIC (PV) SYSTEMS
11/21

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NOTE: This specification covers the requirements for facility-scale solar photovoltaic (PV) systems, and related equipment and materials. Facility-scale systems are typically less than 1 megawatt, maximum DC string input voltage not exceed 1,000 VDC, has the grid interconnection point at the facility's service entrance equipment and generally provides electricity for the facility. Large scale (Utility-scale) systems are considered greater than 1 megawatt and grid connected. Refer to UFC 3-540-08 Utility-Scale Renewable Energy Systems and UFGS-48 14 00 Solar Photovoltaic Systems for the large scale system requirements. Photovoltaic module requirements provided in this document also apply to Section 48 14 00 SOLAR PHOTOVOLTAIC SYSTEMS.

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, suggestions and recommended changes for this guide specification are welcome and should be submitted as a Criteria Change Request (CCR).

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NOTE: Ensure the following information is shown 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, surge protective devices (SPD) if lightning protection is required, 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.

6. Troubleshooting instructions.

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PART 1 GENERAL

1.1 REFERENCES

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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.

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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	(2019; R 2022) Building Code Requirements for Structural Concrete (ACI 318-19) and Commentary (ACI 318R-19)
ACI 318M	(2019; Errata 2022) 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

ASTM INTERNATIONAL (ASTM)

ASTM C260/C260M	(2024) 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 2023) Standard Test Method for Peel Resistance of Adhesives (T-Peel Test)
ASTM D2244	(2025) 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	(2022) Standard Practice for Computing the Colors of Objects by Using the CIE System

ASTM E424	(1971; R 2023) Standard Test Methods for Solar Energy Transmittance and Reflectance (Terrestrial) of Sheet Materials
ASTM E772	(2015; R 2021) Standard Terminology of Solar Energy Conversion
ASTM E1171	(2015; R 2025) 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	(2021) Standard Practice for Operating Xenon Arc Lamp Apparatus for Exposure of 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	(2023) National Electrical Safety Code
IEEE Stds Dictionary	(2009) IEEE Standards Dictionary: Glossary of Terms & Definitions

INTERNATIONAL CODE COUNCIL (ICC)

ICC IBC	(2024) International Building Code
ICC IgCC	(2018) International Green Construction Code

INTERNATIONAL ELECTRICAL TESTING ASSOCIATION (NETA)

NETA ATS	(2025) Standard for Acceptance Testing Specifications for Electrical Power Equipment and Systems

INTERNATIONAL ELECTROTECHNICAL COMMISSION (IEC)

ANSI IEC 60529	(2020) Degrees of Protection Provided by Enclosures
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	(2023) 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 62446	(2018) Photovoltaic (PV) Systems - Requirements for Testing, Documentation, and Maintenance - Part 1: Grid Connected Systems - Documentation, Commissioning Tests and Inspection
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	(2020) 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	(2024) Fire Code
NFPA 70	(2023; ERTA 1 2024; TIA 24-1; TIA 25-2) National Electrical Code
NFPA 70E	(2024) Standard for Electrical Safety in the Workplace
NFPA 780	(2026) 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

U.S. NATIONAL ARCHIVES AND RECORDS ADMINISTRATION (NARA)

29 CFR 1910	Occupational Safety and Health Standards

UL SOLUTIONS (UL)

UL 969	(2017; Reprint May 2023) UL Standard for Safety Marking and Labeling Systems
UL 1449	(2021; Reprint Dec 2022) 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 Jul 2023) UL Standard for Safety Mounting Systems, Mounting Devices, Clamping/Retention Devices, And Ground Lugs For Use With Flat-Plate Photovoltaic Modules And Panels
UL 6703	(2014, Reprint Jun 2024) Standard for Connectors for Use in Photovoltaic Systems
UL Electrical Construction	(2012) Electrical Construction Equipment Directory

1.2 RELATED REQUIREMENTS

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NOTE: Include this optional reference to Section 26 08 00 APPARATUS INSPECTION AND TESTING when it is already being used and referred to for other electrical equipment on the project. Coordinate with optional paragraph in PART 3.

Coordinate photovoltaic equipment with Government's cybersecurity requirements and interpretations. Include this optional reference to Section 25 05 11 CYBERSECURITY FOR FACILITY-RELATED CONTROL SYSTEMS if the photovoltaic system includes remote control or remote access capability.

Use Section 33 71 02 UNDERGROUND ELECTRICAL DISTRIBUTION for an exterior ground mount system.

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Sections 26 20 00 INTERIOR DISTRIBUTION SYSTEM[, 26 08 00 APPARATUS INSPECTION AND TESTING][, 25 05 11 CYBERSECURITY FOR FACILITY-RELATED CONTROL SYSTEMS][and 33 71 02 UNDERGROUND ELECTRICAL DISTRIBUTION] apply to this section with additions and modifications specified herein.

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

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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 and Air Force 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.

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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. Submittals not having a "G" or "S" classification are 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-01 Preconstruction Submittals

Commissioning Plan; G, [_____]

Commissioning Schedule; G, [_____]

SD-02 Shop Drawings

Schematic Diagrams; G, [_____]

Interconnection Diagrams; G, [_____]

Installation Drawings; G, [_____]

Site Plan Drawings; G, [_____]

Riser Diagram and General Notes; G, [_____]

Installation and Assembly Details; G, [_____]

Shop Drawings; G, [_____]

Complete Solar PV System Components and Interconnection Wiring Diagrams; G, [_____]

SD-03 Product Data

Combiner Boxes; G, [_____]

Disconnects; G, [_____]

Inverters; G, [_____]; S

String Inverter 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, [_____]

System Wiring; 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, [_____]

Inverter Startup Tests; G, [_____]

Functional Performance Testing; G, [_____]

SD-07 Certificates

Installer; G, [_____]

Materials; G, [_____]

Warranty; G, [_____]

Cybersecurity Equipment Certification; G, [_____]

Commissioning Agent Qualification; G, [_____]

Seismic Certification; G, [_____]

Wind Certification; G, [_____]

SD-08 Manufacturer's Instructions

Installation Instructions; G, [_____]

Manufacturer's Installation Instructions; G, [_____]

SD-10 Operation and Maintenance Data

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

Training Course; G, [_____]

SD-11 Closeout Submittals

Solar Posted Operating Instructions; G, [_____]

Solar Training Documentation; G, [_____]

Final Commissioning Report; G, [_____]

Warranty; G, [_____]

As-Built Drawings; 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

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

Submit a minimum of three hard copies of drawings for government approval prior to manufacturing and equipment construction or integration. Submit site plan drawings and riser diagram and general notes at a minimum of 610 mm by 915 mm 24 by 36 inches. Submit installation and assembly details at a minimum of 610 mm by 915 mm 24 by 36 inches. Submit at minimum scale of 13 mm 1/2 inch per foot for overview and 51 mm 2 inches per foot for detail.

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

a. 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.

b. Submit shop drawings at a minimum of 280 mm by 432 mm 11 by 17 inches in size using a minimum scale of 7 mm 1/4 inch per foot, for the exception of drawings not required scale. 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.

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

d. 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.

1.6.2.1 Installation and Assembly Drawings and Details

Submit site plan drawings, components and interconnection wiring and general notes, and installation and assembly details drawings prior to start of construction. Drawings must include sufficient detail for all parts of the work to enable the Government to check conformity with the requirements of the contract documents. Include in the site plan drawings: topographic and utility survey; bore logs; soils report; site plan(s); site construction details; structural drawings; structural construction details; site electrical plan; and site electrical construction details. Include in the installation and assembly drawings and details: parts lists; assembly drawings; interconnection wiring diagrams; wire and cable schedules; wire and cable termination schedules; instrument plan; instrument and control wire, conduit and cable schedules; instrument wire and cable termination schedule; control diagrams; control sequence of operation; seismic restraint details; and wind restraint details.

1.6.2.2 "As-Built" and Record Drawings

After completion of construction, submit As-built drawings prepared and certified by the construction contractor, showing in red ink, on-site changes to the original construction details and all underground utilities measured from field benchmarks, accurate to within 1" of centerline of the utility. Immediately record for inclusion into the as-built drawings all modifications to original drawings made during installation. Indicate adequate clearance for operation, maintenance, and replacement of operating equipment devices.

After submittal and approval of "As-built" drawings, submit Record Drawings, prepared and by the project engineer(s) and architect(s), of the original design drawings reflecting all design changes and contractor noted changes in the "As-built" drawings.

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. Provide references for each of these referenced projects.

1.6.5 Standard Materials and Products

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. Provide products with satisfactory commercial or industrial use for [2][_____] years prior to bid opening, and past performance documentation with consistent design and bill of materials. Include applications of equipment and materials under similar circumstances and of similar size. Where [two][_____] or more items of the same class of equipment are required, products will be from a single manufacturer; however, the component parts of the item need not be the products of the same manufacturer unless stated in the technical section. 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 [3][_____] years prior to date of delivery to site must not be used, unless specified otherwise.

[1.6.6 Cybersecurity Equipment Certification

****
NOTE: Select this option if the solar photovoltaic system includes remote control or remote access capability even if the system is separate from an energy management control system. Exercise a Risk Management Framework (RMF) for implementing cybersecurity. Refer to Section 25 05 11 CYBERSECURITY FOR FACILITY-RELATED CONTROL SYSTEMS and UFC 4-010-06 Cybersecurity of Facility-Related Control Systems for requirements on incorporating cybersecurity into control system and for general information on the Risk Management Framework (RMF) process as it applies to control system. Coordinate equipment certification with Government's cybersecurity requirements and interpretations.
****

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.

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

a. Troubleshooting guide[with as-built plans displaying modules identified according groups or zones, coordinated with activity to organize as required].

b. Warranty.

c. Operation instructions.

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

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.

****
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.
****

h. Prices for spare parts and supply list[including spare modules and inverters].

i. Inverter efficiency report and field acceptance test reports.

j. Actual nameplate diagram.

k. Date of purchase.

1.6.7.2 Training Course

Provide training by a factory trained instructor to provide full instructions to designated Government personnel in the operation, maintenance and programming of the specified systems and equipment. Include safety training for first responders including fire department[,_____][,_____][and][_____] representatives. 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. Submit training documentation along with the proposed training date[s], at least [14][_____] days prior to date[s] of proposed training course. Provide training session for [six][_____] personnel specifically oriented to installed equipment, system layout, and user operations.

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 Commissioning Agents

Commissioning Agents Qualifications: Engage commissioning service personnel, that specialize in the types of inspections and tests to be performed.

1.6.11 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

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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.

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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.

****

Provide a list of all applicable warranties for all equipment and components. Include warranty information, names, addresses, telephone numbers, and procedures for filing a claim and obtaining warranty services. 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.

Warrant the overall system for both parts and labor for a minimum period of [5][_____] years. Provide specific warranties for solar photovoltaic modules, inverters, combiner boxes, [and]mounting system[, and cybersecurity].

1.8.1 Solar Photovoltaic Modules

Furnish the solar photovoltaic module manufacturer's written 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. Inverter to be free from defects in material and workmanship for a minimum of [20][_____] years from the date of manufacture. Inverter device installation, transportation, and on-site storage must not exceed 12 months, thereby permitting [19][_____] years of the [20][_____] 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.]

1.8.2.1 Inverter Software Updates Title

Provide, at no cost or charge, any inverter software upgrades that become available during the warranty period.

1.8.3 Combiner Boxes

Combiner boxes to be free from defects in material and workmanship for a period of [5][_____] years.

1.8.4 Mounting System

Provide PV mounting system warranty of minimum 15 years.

1.8.5 Warranty Exclusion

The warranty must cover all system malfunctions and failures except those resulting from misuse, abuse, neglect, fire, vandalism, acts of nature, or other causes beyond the control of the Contractor or manufacturer.

[1.8.6 Cybersecurity During Warranty Period

****
NOTE: Select this option if the solar photovoltaic system includes remote control or remote access capability.
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All work performed on the control system after acceptance must be performed using Government Furnished Equipment or equipment specifically and individually approved by the Government.

]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 CERTIFICATIONS

Provide seismic certification and wind certification, prepared by a

licensed professional engineer or National Recognized Testing Laboratory, (NRTL) for all components and assembled systems in accordance with ICC IBC, ASCE 7-16 state and local building codes. Seismic and wind certifications must demonstrate system must withstand wind and seismic requirements as installed and remain online and functional after a seismic or wind event.

1.11 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

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NOTE: System voltage greater than 1,000 VDC is permitted for the utility-scaled PV systems. Refer to UFC 3-540-08 Utility-Scale Renewable Energy Systems and Section 48 14 00 SOLAR PHOTOVOLTAIC SYSTEMS. Air Force does not allow paralleling facility-scale renewable energy systems with any standby power regardless of whether it is for emergency, Critical Operations Power Systems (COPS), or other purposes.
****

a. The PV system described in this document is a facility-scale less than 1 megawatt with system voltage not exceeding 1,000 VDC, [single][multiple] PV systems with a single service, and is of the grid-connected type which provides a direct interconnection of PV system and grid power service supplying building [that do not utilize engine generators][have backup power systems that would never operate in parallel with the grid power and PV system because backup power generator is supplying power via an automatic transfer switch]. The PV system 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, mounting structure for modules (racking), 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 surge protective device (SPD) complying with NFPA 780 requirements and 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 NFPA 70 and 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.

2.1.1.1 System Wiring

****
NOTE: The possible exposure to a corrosive environment should be carefully examined. Even when the correct conductor size and the selected joining (connecting) method have satisfied all the IEEE 837 test requirements, it may be prudent to choose a larger conductor size to compensate for some gradual reduction in the conductor cross section during the design life of the installation where the soil

environment tends to promote corrosion. Coordinate soil environment with Geotechnical Engineer. All wiring must be copper conductor if the Navy eventually takes ownership of system.
****

System wiring must conform to Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM and must be in accordance with Section 690 of NFPA 70. Cabling exposed to sunlight must be UV resistant.[All wiring must be copper conductor.]

Provide conduits in accordance with Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM. Use galvanized rigid steel conduit above grade and mount on UV resistant high-density polyethylene (HDPE) supports. Conduit below grade must be [Schedule 40 PVC, 25.4 mm 1-inches minimum][Schedule 80 PVC, 25.4 mm 1-inches minimum][as required by Section 33 71 02 UNDERGROUND ELECTRICAL DISTRIBUTION].

[2.1.1.2 Site Design

****
NOTE: Facility-Scale PV system may be up to 1 megawatt. Apply if required.
****

Provide adequate space for personnel, vehicles and equipment throughout the PV array to facilitate installation, inspection and maintenance access to all modules.

]2.1.2 Performance Requirements

****
NOTE: Provide minimum 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 ICC IgCC.

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: https://www.wbdg.org/dod/ufgs/ufgs-forms-graphics-tables
****

****
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. The newest technology will provide solar cells made from organic materials, quantum dots, and hybrid organic-inorganic materials (also known as perovskites). The ultra-high efficiency perovskite compound material with a special crystal structure formed through chemistry which would replace silicon. Advance technology of the fine-tuning a mix of lead and tin would provide about 23 percent efficiency of the new solar cell. In comparison, silicon solar panels on the market today have around an 18 percent efficiency rating. Building-integrated photovoltaics (BIPV) seamlessly blend into building architecture in form of roofs, canopies, facades, and skylight systems. BIPV provides the following benefits: increased thermal and sound insulation; clean and free power output from the sun; decreased O&M costs; zero carbon footprint. Warning: Currently, only monocrystalline and polycrystalline can meet energy density requirements. If 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.

h. Photovoltaic wire, wiring methods, and utilization of locking-type connectors must comply with the requirements of NFPA 70 and UL 6703. Provide USE-2 or RHH or RHW-2 wire, and sunlight-resistant wire when exposed to sunlight.

2.2.1 Crystalline Photovoltaic Module Backsheet

****

NOTE: UFC 3-540-08 Utility-Scale Renewable Energy Systems has same module requirements as are described in paragraph PHOTOVOLTAIC MODULES, list item "a.". Facility-scale PV systems allow a maximum system voltage of 1000 VDC and Utility-scale PV systems allow a maximum system voltage greater than 1000 VDC. Use bracketed option for the Facility-scale PV systems if such a clarification is required.

****

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.
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

2.2.3 Electrical Characteristics

Provide high-power type PV module(s), with typical peak power of not less than [315][_____] watts, plus or minus [3][_____] percent power tolerance, under Standard Test Conditions (STC). The AC output must not be less than [80][_____] percent of the DC kWp rating. The individual current harmonics and TRD shall not exceed the limits specified in IEEE 1547.

The operating voltage corresponding to the power output mentioned above must be at least [54][_____] volts. The open circuit voltage of the PV modules under STC should be at least [64][_____] volts. Operate PV module at an ambient temperature range of [minus 40][_____] degrees C [minus 40][_____] degrees F to [plus 85][_____] degrees C [plus 185][_____] degrees F with [100][_____] percent relative humidity.

2.2.4 Terminal Box

Include a terminal box on the module having a provision for opening for replacing the cable, if required.

2.2.5 Nameplate

Include the following on the module nameplate so as to be clearly visible:

a. Name of the Manufacturer or distinctive logo;

b. Model or Type Number;

c. Serial Number;

d. Year of make;

e. Peak wattage rating;

f. Peak voltage; and

g. Peak current.

2.3 INVERTERS

****

NOTE: Where possible, employ maintainable design practices selecting number of inverters for project to prevent the failure of one inverter from affecting the entire system.

****

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. Verify that a minimum of three inverter manufacturers can provide inverter enclosure made of the selected material.

****

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][polymeric].

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. Data monitoring equipment must be able to sustain an overload across its output terminals up the [150][_____] percent load, while supplying any load within its rating and without reducing its output voltage. Fuse power semiconductors in the inverter with fast acting fuses to prevent cascading failures. Provide each fuse with a blown fuse excluding String and Micro inverters and alarm indicating diodes on the control panel.

]

****

NOTE: Where possible, excluding String and Micro inverters, limit inverter size to 500 kW maximum, with a minimum 96 percent efficiency.

****

j. Rate inverter[s] output as [_____] AC kW at unity (1), [_____] phase, [_____] volts, [_____] maximum power point tracking (MPPT) voltage range. The peak inverter[s] power conversion efficiency must be [96][97][_____] percent or greater.

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. Operate inverter at an ambient temperature range of [minus 20][_____] degrees C [minus 4][_____] degrees F to [plus 50][_____] degrees C [plus 122][_____] degrees F with [95][_____] percent humidity (non-condensing).

****

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.

****

a. Submit String Inverter Efficiency 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 https://www.energy.ca.gov/programs-and-topics/programs/solar-equipment-lists

****

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 larger than 1 megawatt, refer to Section 48 14 00 SOLAR PHOTOVOLTAIC SYSTEMS for large-scaled PV systems.
****

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. Include in the combiner box[es] fuses and a bus to combine the outputs of the strings. Each combiner box must be UL 1741 listed and operate at an ambient temperature range of [minus 25][_____] degrees C [minus 13][_____] degrees F to [plus 57][_____] degrees C [plus 135][_____] degrees F. Provide combiner box capable of at least [12][_____] inputs and an input fuse rating of [15][_____] amps.

e. Provide combiner box output terminals for paralleling two conductors for the PV positive and negative, as well as the equipment ground conductors. Run set of wires from the combiner box to the inverter. Provide overcurrent protection and output disconnecting means listed for intended use and purpose 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 UFC 3-110-03 Roofing, "Photovoltaic Systems – Rack Mounted Systems"

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 Structural Engineering, ASCE 7-16, and IBC modifications in UFC 1-200-01 DoD Building Code.
****

b. Racking and PV array, including modules, hardware, and attachments, must withstand seismic loads, [snow loads], and wind loads as required by ASCE 7-16 and ICC IBC. Coordinate with structural engineer to insure roof will withstand the racking and PV array loads.

****
NOTE: Defer to local code where applicable, UFC 3-301-01 Structural Engineering, ASCE 7-16, and IBC modifications in UFC 1-200-01 DoD Building Code. 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 defined as Environmental Severity Classification Category C1 and C2 as determined by Tables A-1 and A-2, Appendix A, UFC 1-200-01 DoD Building Code. 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. 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.] Design all structural components in a manner commensurate with attaining a minimum [50][_____] year design life. Provide racking compliant with UL 2703.

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

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

****
NOTE: Defer to local code where applicable, UFC 3-301-01 Structural Engineering , ASCE 7-16, and IBC modifications in UFC 1-200-01 DoD Building Code. 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 defined as Environmental Severity Classification Category C1 and C2 as determined by Tables A-1 and A-2, Appendix A, UFC 1-200-01 DoD Building Code, 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. Coordinate helical pile requirements with Section 31 63 26.60 [GROUTED] HELICAL PILES.

]2.6.3 Wind and Seismic Ratings

The mounting system and overall installation must be capable to withstand winds of Category [1][2][3][4] or [5] as defined by the Saffir-Simpson Hurricane Wind Scale for all attachment points and consistent with the manufacturer's installation instructions. Provide wind certifications for all components and assemblies.

All structures and structural elements must be suitable for Seismic Design Category [_____] in accordance with ICC IBC, ASCE 7-16, and all other applicable building codes and standards pertaining to the erection of such structures. 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.

][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. Provide fine and course aggregates in compliance with requirements of ASTM C33, and Portland cement in accordance with requirements of ASTM C150.

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.

l. Welded wire fabric reinforcement must be in accordance with ASTM C185. Deformed bar reinforcement must be in accordance with ASTM 615, Grade 60.

****

NOTE: Coordinate with UFC 1-200-01 DoD Building Code and UFC 3-301-01 Structural Engineering requirements.

****

m. Coordinate reinforced concrete design with environmental severity classification requirements.

]2.7.1 Foundation Anchorage

Anchor mounting structure to concrete pad in accordance with Sections 03 30 00 CAST-IN-PLACE CONCRETE, 05 12 00 STRUCTURAL STEEL, and 05 05 20 POST-INSTALLED CONCRETE AND MASONRY ANCHORS, as required.

][2.8 PV TRACKING SYSTEM

****
NOTE: For tracking array design, refer to UFC 3-440-01 Facility-Scale Renewable Energy Systems which provides the PV tracking system Pros and Cons, 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 PV equipment listed or be evaluated for the application and have a field label applied in compliance with NFPA 70.

****
NOTE: Voltage must not exceed 1,000 VDC.
****

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.
]

****

NOTE: Refer to UFC 3-501-01 Electrical Engineering and UFC 3-560-01 Operation and Maintenance: Electrical Safety requirements. UFC 3-560-01 approved the following types of arc flash label formats: General label; General label referring to OSHA; Details label, compliant with NFPA 70E; General label that refers to a separate arc flash calculation for requirements; Label for equipment that has not received adequate maintenance or testing; Label for equipment where an arc flash calculation identifies an available incident energy greater than 40 cal/cm^2. The arc flash label format can be modified provided that the required information is included. For Army projects, provide arc flash labels in accordance with NFPA 70E.

****

[c. Provide warning signs for arc flash protection in accordance with [NFPA 70E] [as indicated] for all electrical equipment and components that are requiring examination, adjustment, servicing, or maintenance while energized. Provide field installed signs to warn qualified persons of potential electrical arc flash hazards when warning signs are not provided by the manufacturer. Provide marking that is clearly visible and readable from each accessible side to qualified persons before examination, adjustment, servicing, or maintenance of the equipment.

]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 denotes the voltage. The second through [sixth] [_____] positions on the tag identify the circuit.[The next to last position denotes the phase of the circuit and must include the Greek "phi" symbol.] The last position denotes the cable size.][Tag legend must be as indicated.]

2.16 GROUNDING AND BONDING

a. Provide properly sized equipment grounding conductors. Equipment grounding conductors must be insulated stranded copper, except that sizes 10 AWG and smaller must be solid copper. Insulation color must

be continuous green for all equipment grounding conductors, except that wire sizes 4 AWG and larger shall be identified per NFPA 70.

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

c. Bonding conductors must be bare stranded copper, except that sizes 10 AWG and smaller must be bare solid copper. Bonding conductors must be stranded for final connection to motors, transformers, and vibrating equipment.

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

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

[2.17 PV LIGHTNING PROTECTION SYSTEM

****
NOTE: Provide a lighting risk assessment calculation in accordance with UFC 3-501-01 Electrical Engineering and UFC 3-575-01 Lightning and Static Electricity Protection Systems requirements, and if lighting protection is a design requirement, include this paragraph in the Specification.
****

Provide PV Lightning Protection for electrical and mechanical systems in accordance with Section 26 41 00 LIGHTING PROTECTION SYSTEM and NFPA 780.

]PART 3 EXECUTION

3.1 MANUFACTURER'S 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. Ensure wires and conduit are not

installed as a trip hazard.

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

Furnish and install conductors required to connect incoming and outgoing circuits. Install conductors with conduits, boxes, and terminal cabinets in a totally enclosed installation. 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.

h. Rate all enclosures for electrical connections and interconnections for [NEMA 6 in accordance with NEMA 250][or][IP67 in accordance with ANSI IEC 60529].

3.1.3 Disconnects

****

NOTE: UFC 3-440-01 Facility-Scale Renewable Energy Systems and NFPA 70 requires providing a Rapid Shutdown of PV Systems on Buildings. PV system circuits installed on or in buildings must include a rapid shutdown function to reduce shock hazard for firefighters using the Rapid Shutdown Initiation Devices. Multiple PV system initiation device(s) must consist of not more than six switches or six sets of circuit breakers, or a combination of not more than six switches and sets of circuit breakers, mounted in a single enclosure, or a group of separate enclosures.

****

Provide disconnecting means in accordance with NFPA 70 requirements.

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. Equipment disconnecting means or its remote operating device or the enclosure providing access to the disconnecting means must be capable of being locked in the open position when not within sight or not within 3 m 10 ft of the equipment.

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

d. Install disconnecting means with a rapid shutdown function using the rapid shutdown initiation devices as specified in NFPA 70. Each device's "off" position must indicate that the rapid shutdown function has been initiated for all PV systems connected to that rapid shutdown initiation device.

e. Disconnecting means equipment that performs the rapid shutdown function, other than initiating devices, must be listed for providing rapid shutdown protection.

f. Buildings with rapid shutdown disconnecting means must have a permanent label as specified in NFPA 70.

3.1.4 Overcurrent and Overvoltage Protection

a. Install the PV interconnect overcurrent protective device as indicated in accordance with NFPA 70. Overcurrent devices used in PV system dc circuits must be listed for use in PV systems.

****
NOTE: Applies if lightning protection system is required. Use UFC 3-520-01 Interior Electrical Systems requirements also.
****

[b. Install overvoltage surge protective device (SPD) as indicated and in accordance with NFPA 780 and NFPA 70. PV surge protective devices must be listed for use in PV system and marked "DC" or "PV SPD." If the system inverter is more than 30 m 100 ft from the closest combiner or recombiner box, provide additional PV SPDs at the PV output circuit adjacent to the inverter.

]3.1.5 Fire Safety

****
NOTE: Follow UFC 3-440-01 Facility-Scale Renewable Energy Systems requirements for access to Smoke Ventilation. Office of State Auditor (OSA) may provide safety requirements for roof mounted equipment that requires access for periodic maintenance.
****

Firestop conduit that penetrates fire-rated walls, fire-rated partitions, or fire-rated floors in accordance with Section 07 84 00 FIRESTOPPING. For all buildings other than one and two-family dwellings and townhouses provide access to roof mounted PV systems by providing a minimum 1.8 m 6 ft wide clear perimeter around the edges of the roof.[Follow OSA safety requirements for roof mounted PV system equipment that requires access for periodic maintenance.]

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 approves the use of a single made electrode for the system-grounding electrode, if its resistance does not exceed 25 ohms. In most applications, it is desirable to have a maximum resistance of much less, typically 5 ohms or less.
****

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.

****
NOTE: Include if lighting protection is a design requirement. Use UFC 3-550-01 Exterior Electrical Power Distribution requirements.
****

[Provide ground ring electrode in accordance with NFPA 780 encompassing the perimeter of each ground-mounted PV array. Interconnect all building grounding electrode systems, including lighting protection.

]]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.

****
NOTE: The latest analyses of the phenomenon of heat transfer arrived at optimized gap to be between 100 mm to 110 mm 3.94 inches to 4.33 inches beyond which the benefits are negligible.
****

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.

]3.3.2.1 Installation

****
NOTE: Indicate appropriate installation requirements. Account for snow depths and known snowdrift patterns to determine locations and mounting heights in Snowbelt locations.
****

In order to maximize potential energy output from each PV system, the system must be sited to maximize the amount of sunlight it receives daily, without shading from adjacent structures or trees. Existing and proposed land uses adjacent to the PV system must not be taller than the PV location.

a. Site Preparation:

b. Prepare the site for system installation by removing vegetation, grading for adequate drainage and avoid standing water on site[, and excavating and compacting foundations for individual module installation].[Provide access roads, pathways, fencing and other improvements as necessary for site access and security.][Provide vegetation barrier to keep surrounding area free from array-shading vegetation as required.]

c. [Provide walking and vehicle space throughout the PV array to facilitate installation, inspection, and maintenance access to all modules in accordance with NFPA 70 and IEEE C2.][Maintain a minimum ground clearance of [3][_____] m [10][_____] ft around arrays. Maintain a minimum ground clearance of [1][_____] m [3][_____] ft below arrays for all site-specific conditions including possible array-shading vegetation, ground/vegetation maintenance, and/or array-shading snowfall.][Account for snow depths and known snowdrift patterns to determine locations and mounting heights in Snowbelt locations.]

****
NOTE: Comply with UFC 3-260-01 Airfield and Heliport Planning and Design when PV system is sited near an airfield or related facilities and equipment used to sustain flight operations.
****

[d. Airspace Coordination:

e. When PV system to be sited near an airfield or related facilities and equipment used to sustain flight operations submit plans to the airfield manager and safety officer (among other stakeholders) for approval. Contact the DoD Siting Clearinghouse and provide applicable data items required for the DoD Siting coordination. Avoid glare from solar panels following FAA interim policy. Provide Glare and Glint calculation using Sandia Labs software which is maintained by ForgeSolar now. Use link https:/share-ng.sandia.gov/glare-tools.

]][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.

****
NOTE: Coordinate arc flash warning label requirements with paragraph PV EQUIPMENT MARKING AND WARNING LABELS, list item "c" requirements.
****

b. Display information on the arc flash warning labels [in accordance with NFPA 70E][as indicated].

c. Provide the number of signs required to be clearly visible and 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

****
NOTE: Use Section 33 71 02 UNDERGROUND ELECTRICAL DISTRIBUTION for an exterior ground mount system.
****

Perform in accordance with Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM [and 33 71 02 UNDERGROUND ELECTRICAL DISTRIBUTION].

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.

3.10 COMMISSIONING

****
NOTE: Section 01 91 00.15 BUILDING COMMISSIONING is intended for building systems, however, the basic requirements are applicable to PV commissioning processes. Section 01 91 00.15 will need to be tailored for PV systems when compiling project specifications.
****

Conduct Commissioning, after the system is installed and is ready for operation, in accordance with Section 01 91 00.15 BUILDING COMMISSIONING, item (6) renewable energy generation, to verify that the completed and installed system meets the requirements of IEEE 1547. Tailor for non-building systems.

3.10.1 Commissioning Agent Qualification

Individual qualified in testing protective equipment (e.g., professional engineer, factory-certified technician, licensed electrician with experience in testing protective equipment) must perform or directly supervise commissioning tests.

3.10.2 Commissioning Plan and Schedule

Develop and implement a commissioning plan and commissioning schedule in accordance with Section 01 91 00.15 BUILDING COMMISSIONING.

3.10.3 Start-up Pre-functional Checklists

Carry out a checklist of startup requirements and conduct a series of safety tests to ensure proper installation, safe operation, and performance conforming to specification.

3.10.4 Functional Performance Testing

Prepare test procedures and conduct functional performance testing of the installed system. Include the following test requirements:

a. All inverter startup tests as specified by the inverter manufacturer in the inverter operation manual;

b. Actual power;

c. Loss of grid;

d. Grid resume;

e. Data monitoring check out;

f. V_{oc} measurement of every source circuit and log it;

g. Verify tightness of all wiring terminations;

h. Verify proper markings and labeling of all wire terminations and enclosures;

i. Verify startup/shut down procedures;

j. Verify system [5][_____] minutes delay upon restart;

k. Verify PV array quick connectors are fully mated and wires are neatly secured;

l. Verify no debris on the modules, no damaged or broken modules;

m. Verification and inspections (see IEEE 1547.1 7.2)

n. Field-conducted type and production tests (see IEEE 1547 7.3)

o. Unintentional islanding functionality test (see IEEE 1547.1)

p. Cease-to-energize functionality test (see IEEE 1547.1)

q. Unintentional islanding functionality test (see IEEE 1547.1)

r. Cease-to-energize functionality test (see IEEE 1547.1 7.5)

s. Revised settings (see IEEE 1547.1 7.6)

3.10.5 Functional Performance Testing Results

Coordinate, observe and record the results of the functional performance testing. Coordinate retesting as necessary until satisfactory performance is verified. Verify the intended operation of individual components and system interactions under various conditions and modes of operation.

Document items of non-compliance in materials, installation or operation. Immediately address observed non-conformance and deficiencies in terms of notification to responsible parties, and provide recommended actions to correct deficiencies.

3.10.6 Final Commissioning Report

Prepare and submit final commissioning report. Summarize all tasks, findings, conclusions, and recommendations of the commissioning process in accordance with IEC 62446. Include the results of all tests and a listing of the final settings.

3.11 FINAL ACCEPTANCE

The acceptance of the solar PV system occurs only after all deficiencies identified by the functional acceptance tests and commissioning report are corrected[, and the system operates successfully during a [30][_____] day initial testing period].

The Contracting Officer must sign appropriate certificates, if equipment and systems are operating satisfactorily in accordance with the specifications, stating the system's operation has been tested and accepted at the end of the final start-up and testing.

3.12 CLOSEOUT ACTIVITIES

3.12.1 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.

3.12.2 Instructor's Qualification Resume

****
NOTE: Use the most appropriate and available option to provide the necessary training.
****

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.

3.12.3 Training

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

Furnish training service by a factory-trained representative. Document

that each qualified employee has received the required training in accordance with 29 CFR 1910. Maintain all training documentation in a central location for the entire employee's employment duration. Minimum documentation data includes employee's name, training name, and date(s) of training.

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 --