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USACE / NAVFAC / AFCEC **UFGS-48 14 00 (May 2017)**

Preparing Activity: AFCEC

UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated January 2025
****

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DIVISION 48 - ELECTRICAL POWER GENERATION

SECTION 48 14 00

SOLAR PHOTOVOLTAIC SYSTEMS

05/17

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SECTION 48 14 00

SOLAR PHOTOVOLTAIC SYSTEMS
05/17

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NOTE: This guide specification covers the requirements for large scale solar photovoltaics (PV) systems, and related equipment and materials. Large scale is considered greater than one megawatt capacity and grid connected.

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: Show the following information on the project drawings:

1. Mounting surface features.

2. Locations of solar PV modules, inverters, combiner and junction boxes, conduits and raceways, and other related equipment and materials.

3. Circuit wiring diagram of solar PV system.

4. Troubleshooting instructions.
****

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 NATIONAL STANDARDS INSTITUTE (ANSI)

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

AMERICAN SOCIETY OF CIVIL ENGINEERS (ASCE)

ASCE 7-10	(2010; Errata 2011; Supp 1 2013) Minimum Design Loads for Buildings and Other Structures

ASTM INTERNATIONAL (ASTM)

ASTM A240/A240M	(2024b) Standard Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications
ASTM D709	(2017) Standard Specification for Laminated Thermosetting Materials
ASTM E772	(2015; R 2021) Standard Terminology of Solar Energy Conversion
ASTM G173	(2003; R 2012) Standard Tables for Reference Solar Spectral Irradiances: Direct Normal and Hemispherical on 37 Degree Tilted Surface

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

IEEE 80	(2013) Guide for Safety in AC Substation Grounding
IEEE 142	(2007; Errata 2014) Recommended Practice for Grounding of Industrial and Commercial Power Systems - IEEE Green Book
IEEE 242	(2001; Errata 2003) Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems - Buff Book
IEEE 1547	(2018) Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces
IEEE 1547.1A	(2015) Standard for Conformance Test Procedures for Equipment Interconnecting Distributed Resources with Electric Power Systems -- Amendment 1
IEEE 1547A	(2020) Standard for Interconnecting Distributed Resources with Electric Power Systems - Amendment 1
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

INTERNATIONAL ELECTRICAL TESTING ASSOCIATION (NETA)

NETA ATS	(2021) 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 62446	(2018) Photovoltaic (PV) Systems - Requirements for Testing, Documentation, and Maintenance - Part 1: Grid Connected

	Systems - Documentation, Commissioning Tests and Inspection

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

NEMA 250	(2020) Enclosures for Electrical Equipment (1000 Volts Maximum)

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 70	(2023; ERTA 1 2024; TIA 24-1) National Electrical Code
NFPA 70E	(2024) Standard for Electrical Safety in the Workplace

U.S. DEPARTMENT OF DEFENSE (DOD)

UFC 3-301-01	(2023; with Change 2, 2024) Structural Engineering
UFC 3-501-01	(2015; with Change 2, 2023) Electrical Engineering

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

29 CFR 1910	Occupational Safety and Health Standards

UL SOLUTIONS (UL)

UL 96	(2016; May 2023) UL Standard for Safety Lightning Protection Components
UL 467	(2022) UL Standard for Safety Grounding and Bonding Equipment
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 Subject 3703	(2011; Edition 2014) Outline of Investigation for Solar Trackers

1.2 RELATED REQUIREMENTS

****
NOTE: Include Section 26 08 00, APPARATUS INSPECTION AND TESTING on all projects involving medium voltage and specialized power distribution equipment.
****

[Section 26 08 00, APPARATUS INSPECTION AND TESTING apply to this section with additions and modifications specified herein.

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

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

1.3 DEFINITIONS

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

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

1.4 SUBMITTALS

****

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

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

****

NOTE: Permits are assumed to be obtained by firm holding design responsibility. Ensure this is clarified in contract bid package.

****

SD-01 Preconstruction Submittals

Commissioning Plan; G, [_____]

Commissioning Schedule; G, [_____]

SD-02 Shop Drawings

Site plan drawings; G, [_____]

Riser diagram and general notes; G, [_____]

Complete solar PV system components and interconnection wiring diagrams; G, [_____]

Shop Drawings; G, [_____]

Installation and Assembly Details; G, [_____]

SD-03 Product Data

Photovoltaic Modules; G, [_____]

Inverters; G, [_____]

Disconnect; G, [_____]

Combiner Boxes; G, [_____]

Monitoring equipment; G, [_____]

System wiring; G, [_____]

Ground mounting structure; G, [_____]

Sample warranty certificate; G, [_____]
Submit for all materials to be provided. Submit data sufficient to indicate conformance to specified requirements.

SD-05 Design Data

Design Calculations; G, [_____]

SD-06 Test Reports

Inverter startup tests; G, [_____]

Functional Performance Testing; G, [_____]

SD-07 Certificates

Materials; G, [_____]

Commissioning Agent Qualification; G, [_____]

Seismic Certification; G, [_____]

Wind Certification; G, [_____]

SD-08 Manufacturer's Instructions

Installation Instructions; G, [_____]

SD-10 Operation and Maintenance Data

Data Package 5

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

In each of the publications referred to herein, consider the advisory provisions to be mandatory, as though the word, "must" had been substituted for "should" wherever it appears. Interpret references in these publications to the "authority having jurisdiction," or words of similar meaning, to mean the Contracting Officer. 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 Drawings

Submit minimum of three (3) hard copies of drawings for government approval prior to manufacturing and equipment construction or integration. Submit shop drawings at a minimum of 11 by 17 inches in size using a minimum scale of 1/4 inch per foot, for the exception of drawings not requiring scale. Submit site plan drawings and riser diagram and general notes at a minimum of 24 by 36 inches. Submit Installation and Assembly Details at a minimum of 24 by 36 inches. Submit at minimum scale of 1/2 inch per foot for overview and 2 inches per foot for detail.

1.6.2.1 Product Drawings

Submit complete detailed product drawings for the solar PV system consisting of shop drawings and product data sheets. Include in the shop drawings [one][three] [four] wire diagrams, utility interconnection diagrams, switchboard and switchgear drawings layout and arrangement of PV modules, support and mounting mechanism, inverters, combiner boxes, AC and DC disconnects, equipment enclosures, conduits, monitors, meters, and all other accessories associated with the installation of the PV system. Provide equipment dimensions, weights and structural mounting details.

Provide design Calculations.Include nameplate data, size, and capacity of each PV module. Include all assumptions such as applicable wind speed, snow and seismic loads. Include applicable federal, military, industry, and technical society publication references.

1.6.2.2 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. Include sufficient detail on drawings 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.

1.6.2.3 "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. Prepare "as-built" on a minimum of 24 by 36 inches vellum using red ink.

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 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.

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.

1.6.3.1 Alternative Qualifications

Products having less than a [2][_____]-year field service record will be acceptable if a certified record of satisfactory field operation of not less than [6,000][_____] hours, exclusive of the manufacturers' factory or laboratory tests, is furnished. These alternative qualifications do not apply to materials in Section 2.2 of Section 26 31 00 FACILITY-SCALE SOLAR PHOTOVOLTAIC (PV) SYSTEMS.

1.6.3.2 Material and Equipment Manufacturing Date

Do not use products manufactured more than [3][_____] years prior to date of delivery to site, unless specified otherwise.

1.6.4 Operations and Maintenance Data

Submit operation and maintenance Data Package 5 in accordance with Section 01 78 23, OPERATION AND MAINTENANCE DATA and as specified herein.

1.6.5 Commissioning Agents

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

1.6.6 Installers

Demonstrate that installers have successfully installed at least [four][_____] projects that, in aggregate, equal or exceed the size of the proposed project. Provide references for each of these referenced projects.

1.6.7 Qualified Testing Organization

Engage the services of a qualified testing organization to provide inspection, testing, calibration, and adjustment of the solar PV system and equipment listed herein. The organization must be independent of the supplier, manufacturer, and installer of the equipment. The organization must be a First Tier Contractor.

The organization must have been regularly engaged in the testing of electrical materials, devices, installations, and systems for a minimum of [5][_____] years. The organization must have a calibration program, and test instruments used to be calibrated in accordance with NETA ATS.

1.6.8 Permitting

The [Owner][Contractor] is responsible for obtaining all necessary development permits and regulatory and utility service provider approvals prior to construction.

The [Owner][Contractor] is responsible for obtaining all necessary electrical and building permits and inspections.

1.6.9 Training

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.

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.

1.7 DELIVERY, STORAGE, AND HANDLING

Store solar PV panel modules in the original packaging according to the manufacturer's guidance, and remain in packaging until day of installation. If a solar PV module is removed from its packaging, store according to the manufacturer's guidance. Do not store solar PV panel modules on-site for more than [12][_____] months.

1.8 WARRANTY

Warrant the overall system for both parts and labor for a minimum period of [5][_____] years. Provide the following component specific warranties:

a. Photovoltaic Modules: Minimum warranty period of 25-year for linear minimum output and 10-years for workmanship, material, visual, and manufacturing defects from the date of manufacture followed by an additional fifteen (15) years at not more than 20 percent power loss.

b. Ground Mounting Structure: Mounting structure system hardware to be free from defects in the material and workmanship for a minimum period of [10][_____] years.

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

d. Inverters: Inverters to be from defects in material and workmanship for a minimum period of [20][_____] years.

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.

1.8.1 Inverter Software Upgrades

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

1.8.2 Warranty Exclusions

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.

1.9 CERTIFICATIONS

Provide Seismic Certificationand 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 7-10 state and local building codes. Seismic and wind certifications must demonstrate system will withstand wind and seismic requirements as installed and remain remain online and functional after a seismic or wind event.

1.10 HEALTH AND SAFETY REQUIREMENTS

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

PART 2 PRODUCTS

2.1 SYSTEM DESCRIPTION

Provide utility scale solar PV system feeding AC power to utility grid in accordance with IEEE 1547 and local utility regulations. The PV system must comply with these specifications, all applicable codes and standards, all construction documents, and all local authorities having jurisdiction.

Installation must consist of either a fixed-axis, single- or dual-axis utility scale-ground mount system. Tracking requirements must comply with local siting requirements regarding reflectivity restrictions and airspace safety requirements. Support structures must either be individual modules or where applicable, groups of panels configured for shade structures. Provide all necessary accessories for a complete, secure, and operational solar PV system. Commercial-grade and residential-grade rooftop systems are excluded from this UFGS.

2.1.1 System Requirements

2.1.1.1 System Characteristics

The system characteristics include [_____] minimum rated [kW][MW] DC output, [_____] minimum [kWh][MWh] AC per year, [_____] system voltage, and [fixed axis][tracking [one-][two-]axis] ground-mounted at full load rated power [1][_____] percent mean ambient summer operating temperature. Rate all electrical equipment for the current and voltage ratings appropriate for the application.

The system must be rated for outdoor installation. Provide system equipment capable of operating under the location's maximum and minimum documented temperatures during summer and winter times. The entire system must be rated and warranted to withstand and operate under these conditions.

2.1.1.2 Capacity Ratings

Specify rated PV system capacity in direct current (DC) [kilo][mega]watts

peak under both Standard Test Conditions (STC) and Photovoltaics for Utility Scale Applications (PVUSA) Test Conditions (PTC) ratings.

a. The STC rating assumes direct current referred as "[k][M]Wdc-STC". It is also referred as [kilo][mega]watts peak, or "[k][M]Wp". Specific PV module manufacturer maximum and minimum power data must be specified for this rating. The STC rating is based on 1,000 watts/m^2 solar irradiance, 25 degrees C cell temperature, air mass equal to 1.5, and ASTM G173 standard spectrum.

b. The PTC rating is based on 1,000 watts/m^2 solar irradiance, 20 degrees C ambient temperature and 1 meter/second wind speed at 10 meters above ground level.

2.1.1.3 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.

****

System wiring [must conform to Section [_____] and]must be in accordance with Section 690 of NFPA 70. The conductors used must have a temperature rating of [90][_____] degrees C or higher and be sized according to the appropriate DC or AC voltage application. Cabling exposed to sunlight must be UV resistant. [All wiring must be copper conductor if Navy eventually takes ownership of system.]

[Provide conduits in accordance with Section [_____].]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, minimum.

2.1.1.4 Site Design

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

2.2 PHOTOVOLTAIC MODULES

****

NOTE: Include in this section specifying CEC information and requirements for projects abiding by California Energy Commission.

****

Utilize PV modules with [crystalline silicon][ribbon sheet][thin film] technology and conform to Section 26 31 00 FACILITY-SCALE SOLAR PHOTOVOLTAIC (PV) SYSTEMS. Include bypass diodes with each PV module installed in the module junction box.

2.2.1 Compliance

The PV modules must comply with the Buy American Act[and must be listed on the California Energy Commission's PTC list][and must qualify for eligibility under the California Solar Initiative (CSI) Program]. The system must comply with IEC 61215 or IEC 61646.

2.2.2 Electrical Characteristics

Provide high-power type PV module(s), with typical peak power of not less than [315][] watts, +/- [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 are not to exceed the limits specified in IEEE 1547.

The operating voltage corresponding to the power output mentioned above should 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.

2.2.3 Terminal Box

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

2.2.4 Nameplate

Include the following on the module namplate 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

Provide solid state type inverter unit capable of accepting the output of the photovoltaic panels and providing rated output as indicated. Provide the inverter with monopole, negative grounded, and positive grounded array configuration capabilities.

2.3.1 Listings

Provide inverter listed on the California Energy Commission's PTC list[and must qualify for eligibility under the CSI Program]. The inverter must be UL 1741 listed and conform to IEEE 1547A and NFPA 70 standards.

2.3.2 Ratings

Rate the inverter's output as [250][500][_____] kW, [600][1,000][_____] Vdc, 3 phase, [320-600][420-850][_____] maximum power point tracking (MPPT) voltage range. The peak inverter power conversion efficiency must be [95][97][_____] percent or greater.

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).

2.3.3 Safeties and Protection

Equip each inverter with the following safeties and Protection:

a. DC input disconnect;

b. Surge protection;

c. Ground fault interrupter;

d. Isolation transformer;

e. AC output disconnect; and

f. Data Monitoring Equipment/System.

The inverter 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 and alarm indicating diodes on the control panel.

2.3.4 Features

Include each inverter with the following:

a. Automatic operation including start-up, shutdown, self-diagnosis, and fault detection;

b. Digital Signal Processor (DSP) based controls with self-diagnostics and [remote][local] display of operating status;

c. Over- and under-voltage and frequency protection, shutting down the inverter in compliance with UL 1741; and

d. Anti-islanding protection to prevent back-feeding inverter generated power to the grid in the event of a utility outage.

Provide inverter in [floor-mount][wall-mount][support structure mount], NEMA [1][3R][4][4X][6][6P], [steel][aluminum][stainless steel][polymeric] enclosure in accordance with NEMA 250.

2.4 COMBINER BOXES

Provide combiner box[es] in [wall-mount][pole-mount], NEMA [3R][4X][_____], [steel][aluminum][stainless steel] enclosure in accordance with NEMA 250. 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. Include output circuit disconnecting means listed for intended use and purpose.

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. Combiner output must be compatible with inverter input.

2.5 GROUND MOUNTING STRUCTURES

Provide array ground mounting structure for PV modules that provides the designed panel tilt. The mounting system must be [ground][tracking] mounting type [, [two][four] rails][, [one][two] axis], and be [UL 2703] and [UL Subject 3703] listed.

Design all structural components in a manner commensurate with attaining a minimum [30][_____] year design life. Array mounting hardware must be compatible with the site considerations and environment. Aluminum and stainless steel components and hardware are preferred.

2.5.1 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 Hurrican Wind Scalefor 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 UFC 3-301-01, ICC IBC, ASCE 7-10, and all other applicable building codes and standards pertaining to the erection of such structures.

2.6 CAST-IN-PLACE CONCRETE

Provide concrete foundations for ground mounting structural members as specified in Section 03 30 00 CAST-IN-PLACE CONCRETE and in accordance with manufacturer's recommendations.

Provide mounting assembly and connections where system is to be installed on a concrete structure.

2.7 METERING AND POWER MONITORING

Provide and install a revenue grade alternating current (AC) Interval Data Recording (IDR) meter, located on the output side of the inverter, complete with industry standard telemetry for communications with Ethernet, cellular or other common output capabilities. Meter must conform to the Owner's[, Navy's,] and Electrical Company metering requirements.[If the power is tied into the Navy's internal electrical grid, then advanced metering infrastructure (AMI) meters are to be installed. Provide new AMI meters that are compatible with installation's current AMI system.]

2.7.1 Meter Characteristics

The meter must be UL listed and have an operating temperature range of [minus 20][_____] degrees C[minus 4][_____] degrees F to [plus 70][_____] degrees C[plus 158][_____] degrees F with a humidity range of [95][_____] percent relative humidity (RH) non-condensing. Provide the meter conforming to ANSI C12.1.

Provide meter capable of measuring kWh, Demand, Instantaneous power, volts, amps, watts, VAR and VA per phase.

2.7.2 Power Monitorning System

[Provide and connect][Connect] meter to a power monitoring/data collection system recording solar production through Time of Use (TOU) increments applicable to the installation and utility standards, with a minimum [15][_____] minute intervals and [30][_____] day memory.

2.8 POSTED OPERATING INSTRUCTIONS

Provide posted operating instructions for solar PV system equipment laminated between thermoplastic sheets. After operating instructions are approved, install where directed.

2.9 MANUFACTURER'S NAMEPLATE

Provide on each equipment item, including PV panels, a nameplate bearing all manufacturer's information securely affixed in a conspicuous place. Nameplates exposed to weather are to be ASTM A240/A240MType 316 stainless steel with stamped engraving.

2.10 FIELD FABRICATED NAMEPLATES

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

Provide field fabricated nameplates in accordance with ASTM D709 as specified or as indicated on the drawings. Minimum size of nameplates is 25 by 65 mm 1 by 2.5 inches. Lettering is a minimum of 6.35 mm 0.25 inch high normal block style.

2.11 WARNING SIGNS

Provide clearly visible warning signs for arc flash protection in accordance with UFC 3-501-01 and NFPA 70E for all electrical equipment and components that are required to examine, adjust, service, or maintain while energized.

2.12 CABLE TAGS IN MANHOLES, HANDHOLES, AND VAULTS

Provide machine printed polyethylene cable tags for each cable entering or leaving manholes, handholes, and vaults. Do not provide handwritten tags.

2.13 GROUNDING AND BONDING

NFPA 70, IEEE 80, IEEE 142, IEEE 242, and IEEE C2, except that grounds and

grounding systems must have a resistance to solid earth ground not exceeding 5 ohms.

2.13.1 Ground Rods

Provide ground rods made of [copper-clad steel] [solid copper] conforming to conform to UL 467 with minimum diameter of [19][_____] mm/[3/4][_____] in and length of [3][_____] m/[10][_____] ft.

2.13.2 Ground Plates

Provide grounding plates made of [copper-clad steel][iron][stainless steel] [solid copper] conforming to UL 96.

2.13.3 Ground and Bonding Conductors

Equipment grounding conductors must be insulated stranded copper, except that sizes No. 10 AWG and smaller must be solid copper. Insulation color must be continuous green for all equipment grounding conductors, except that wire sizes No. 4 AWG and larger must be identified per NFPA 70NEC.

Bonding conductors must be bare stranded copper, except that sizes No. 10 AWG and smaller must be bare solid copper. Bonding conductors must be stranded for final connection to motors, transformers, and vibrating equipment.

2.13.4 Ground Connections

Below Grade and Inaccessible Locations: Exothermic-welded type connectors.

Above Grade:

a. Bonding Jumpers: Listed for use with aluminum and copper conductors. For wire sizes No. 8 AWG and larger, use compression-type connectors. For wire sizes smaller than No. 8 AWG, use mechanical type lugs. Connectors or lugs must use [zinc-plated][cadmium-plated] steel bolts, nuts, and washers. Bolts must be torqued to the values recommended by the manufacturer.

b. Connection to Building Steel: Exothermic-welded type connectors.

c. Connection to Grounding Bus Bars: Listed for use with aluminum and copper conductors. Use mechanical type lugs, with [zinc-plated][cadmium-plated]/ steel bolts, nuts, and washers. Bolts must be torqued to the values recommended by the manufacturer.

d. Connection to Equipment Rack and Cabinet Ground Bars: Listed for use with aluminum and copper conductors. Use mechanical type lugs, with [zinc-plated][cadmium-plated] steel bolts, nuts, and washers. Bolts must be torqued to the values recommended by the manufacturer.

2.14 Lightning Protection System

Provide Lightning Protection System and components in accordance with Section 26 41 00 LIGHTNING PROTECTION SYSTEM.

PART 3 EXECUTION

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NOTE: Use and coordinate paint and coating requirements with Section 09 90 00, PAINTS AND COATINGS when provided in the job. Use the second bracketed option when Section 09 90 00 is not provided or when requirements are beyond what is specified in Section 09 90 00.

****

3.1 INSTALLATION

3.1.1 Site Preparation

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.

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 3 maround 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.

3.1.2 Equipment Installation

Install all equipment and all required wiring for a complete and operational system. Follow manufacturer's guidelines for the installation of the array components, including mounting hardware and PV modules. Provide required conductor terminations to devices for a complete system to function as specified and indicated. Complete installation must comply with all local building codes, manufacturer's instructions, and applicable industry standards.

3.1.3 Conductor Installation

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 buried cable per Section 33 71 02 UNDERGROUND ELECTRICAL DISTRIBUTION. Comply with IEEE 1547 for interconnection with utility providers.Color-code all conductors per Section 26 05 19.00 10, INSULATED WIRE AND CABLE and as recommended by the equipment manufacturer.

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

3.2 GROUNDING

Ensure PV system grounding installation is in accordance with NFPA 70 and IEEE C2.

3.2.1 Grounding Electrodes

Provide ground rods as specified in Section 33 71 02 UNDERGROUND

ELECTRICAL DISTRIBUTION. Connect grounding conductors to ground rods by exothermic weld[or compression connector].

3.3 FOUNDATIONS OF EQUIPMENT AND ASSEMBLIES

[Conduct soil borings and provide recommended foundation design by a licesened geotechnical engineer.] [Design foundation in accordance with foundation design recommenations.] Construct equipment foundations.

3.3.1 Ground Mounted Structures

Provide reinforced concrete foundations for ground mounted structures. Provide 4" reinforced concrete housekeeping pads for electrical equipment other than PV structures.

Provide excavating and backfilling in accordance with Section 31 00 00 EARTHWORK. Perform concrete work in accordance with Section 03 30 00 CAST-IN-PLACE CONCRETE. Coordinate provision of utility warning and identification tape with backfill operation. Provide tapes above buried lines at a depth of 8 to 12 inches below finish grade.

3.4 FIELD APPLIED PAINTING

Apply field painting as specified in Section 09 90 00 PAINTS AND COATINGS.

3.5 FIELD FABRICATED NAMEPLATE MOUNTING

Provide equipment nameplates as indicated.

3.6 WARNING SIGN MOUNTING

Provide the number of warning signs required to be readable from each accessible side. Locate and space signs in accordance with NFPA 70E.

3.7 CABLE TAG INSTALLATION

Install cable tags in manholes, handholes, and vaults as specified, including each splice. Locate tags over any fireproofing, if any, and clearly visible on cabling without disturbance in manholes, handholes, and vaults.

Identify and label all cables per NFPA 70.

3.8 [FACTORY SYSTEM TESTING]

[Provide testing of the complete system in accordance with IEEE 1547.1A. IEEE 1547 allows for type testing to be performed on complete systems, multifunction relays, discrete devices, or any combination. If type testing is performed on anything other than a fully integrated system, some of the component times may not be available. In these cases, production and/or commissioning tests must be conducted to fully demonstrate the ability of the complete system to comply with the timing required by IEEE 1547.]

3.9 FIELD QUALITY CONTROL

3.9.1 Manufacturer's Field Service

Provide the services of factory trained and approved field service

engineer during system installation, testing and commissioning.

3.10 COMMISSIONING

****
NOTE: Sections 01 91 00.15 BUILDING COMMISSIONING, are intended for building systems, however, the basic requirements are applicable to PV comissioning 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 of the 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 functionalacceptance tests and commissioing 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

Demonstrate, upon completion of functional acceptance tests, that all circuits and devices are in proper operating condition and performing as intended.

3.12.2 Training

Furnish training service by a factory-trained representative for a period of [5][_____] calendar days. 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.

-- End of Section --