Special Specification 6063

Intelligent Transportation System (ITS) Solar Power System

1. DESCRIPTION

Furnish, install, relocate, or remove an integrated Intelligent Transportation System (ITS) solar power system at locations shown on the plans, or as directed.

A solar power system is co-located with and supplies operational power for designated ITS field equipment at locations as shown on the plans. The solar panel power supply system must supply power service for the field equipment. Furnish and install all of the components described in the specification and configure the equipment as indicated on the plans.

2. MATERIALS

Provide materials that comply with the details shown on the plans, the requirements of this Item, and the pertinent requirements of the following Items:

- Item 416, “Drilled Shaft Foundation,”
- Item 421, “Hydraulic Cement Concrete,”
- Item 440, “Reinforcing Steel,”
- Item 442, "Metal for Structures,"
- Item 445, "Galvanizing,"
- Item 449, “Anchor Bolts,”
- Item 618 “Conduit,”
- Item 620, "Electrical Conductors,"
- Item 624 “Ground Boxes,”
- Item 627 “Treated Timber Poles,” and
- Item 687 “Pedestal Pole Assemblies.”

3. EQUIPMENT

Provide labor, equipment and materials to employ solar-generated, battery-backed power for the assigned field equipment specified in the plans, or as directed. Install all equipment, including batteries and charge controller, in a suitably sized enclosure.

Size the enclosure to house the solar chargers, batteries, lightning protection equipment, and all co-located ITS field equipment shown on the plans or as directed.

Furnish a solar power system that supplies the design electrical load for up to 24 hr. per day with 3 or 5 days of battery backup, as described in the plans, and generally consisting of the following:

- Photovoltaic (PV) modules with mounts or racks, and mounting brackets for affixing the modules to a pole as shown on the plans. Ensure mounting and bracket assembly has all galvanized steel or heavy gauge-mill aluminum construction. Provide adjustable tilt mounts that can be repositioned to an appropriate angle to maximize seasonal solar radiation.,
- 12 VDC sealed, valve-regulated, absorbed glass mat (AGM), maintenance-free batteries,
- maximum power point tracking (MPPT) photovoltaic charge controllers and monitoring units,
- one toggle-type power switch for emergency shutoff, and

- external conduit, wiring cable and conductors (as recommended by the supplier) between the following:
- photovoltaic module to cabinet back panel,
- battery interconnect,
- batteries to cabinet back panel, and
- wiring between components in cabinet.

Pre-set the equipment, optimize photovoltaic module direction, and configure hardware components to allow automatic operation. Furnish and install a fully operational assembly with all cabling and terminations matched to support the selected components. Use the component sizing chart, Table 1 or Table 2, shown below to size the individual components based on the planned electrical load and days autonomy:

Table 1
Solar Power System Component Sizing – 3 Days Autonomy

Design Load (Watts)	100	90	80	70	60	50	40	20
Solar Array Size (Watts)[2]	1440	1296	1152	1008	864	720	576	288
Battery Capacity (AH)	750	675	600	525	450	375	300	150
Total Controller Capacity (Amps)	120	108	96	84	72	60	48	24
1. Components Sized Based On The Following Performance Requirements: - 3 Days of Autonomous Operation - Maximum Battery Discharge of 80% - Recharge to Capacity in 5 hours of sunlight after 80% battery discharge. 2. Panels to be selected using PVUSA Test Conditions (PTC)								

Table 2
Solar Power System Component Sizing – 5 Days Autonomy

Design Load (Watts)	100	90	80	70	60	50	40	20
Solar Array Size (Watts)[2]	2400	2160	1920	1680	1440	1200	960	480
Battery Capacity (AH)	1250	1125	1000	875	750	625	500	250
Total Controller Capacity (Amps)	200	180	160	140	120	100	80	40
1. Components Sized Based On The Following Performance Requirements: - 5 Days of Autonomous Operation - Maximum Battery Discharge of 80% - Recharge to Capacity in 5 hours of sunlight after 80% battery discharge. 2. Panels to be selected using PVUSA Test Conditions (PTC)								

Size the components of the system considering how many days of autonomous operation are needed and future maintenance costs. Furnish, install, and test the solar panel power supply system, and ensure it meets the following requirements:

3.1. **Solar Generator.** Ensure the system solar generator provides at least the total power output shown for the planned electrical load. Supply and install the appropriate number and size of PV modules needed to meet the minimum power requirements shown in Table 1 or 2 as required by the plans. Use photo voltaic USA (PVUSA) test conditions (PTC) ratings.

Supply industrial grade, mono-crystalline or poly-crystalline type solar modules. Consumer grade modules are not acceptable. Ensure that the PV modules meet the following minimum requirements:

- minimum output voltage of 12 VDC,
- minimum area efficiency rating of 15%,
- at least 2 bypass diodes, installed at the factory,

- include an ultraviolet (UV) resistant, Ingress Protection (IP) 66 rated junction box providing wire termination for up to No. 6 AWG wiring with the PV module,
- hail impact resistance up to 1 in. diameter at 50 mi. per hr., and
- UL 1703 listing.

Ensure PV modules, regardless of wattage size, shares common mounting holes for mounting so that a single mounting structure will accommodate the entire module line.

PV modules may be wired in “strings” of panels wired in series, which are then wired in parallel to other strings. Ensure that the open circuit voltage of any single string of PV modules does not exceed 127 V.

Construct PV modules with a tempered glass surface and an industrial grade anodized aluminum frame that completely surrounds and seals the module laminate. Ensure construction is consistent with the demands of installation near humid salt air environments.

Design and construct the photovoltaic module mounting assembly of galvanized steel (ASTM A-153 Class A) or aluminum. The mounting assembly must be of adequate design and strength to provide a means of securely attaching the PV module frame to a pole. Provide a mounting assembly capable of 360° horizontal orientation with a means of locking the bracket at an inscribed angular position about the pole. Ensure the mounting assembly is designed and installed to prevent module re-positioning during 110 mph wind conditions.

Label all PV modules with open-circuit voltage, operating (maximum power) voltage, maximum permissible voltage, operating (maximum power) current, short-circuit current, and maximum power.

Provide a warning label on all DC junction boxes warning that the active parts inside the boxes are fed by a PV array and may still be energized after isolation.

Provide a DC disconnect toggle switch to the solar array at a readily accessible location. Label with system information including maximum power current, maximum power voltage, maximum system voltage, short-circuit current, and maximum rated output current of charge controller at the DC disconnect. National Electrical Code (NEC) 690.14(C)1 and 690.31(E).

Mark each PV system disconnect as such. NEC 690.14(C)(2) and 690.14(C)(3).

Provide overcurrent protection for the PV source circuit in conformance with NEC 690.9(A); 240.

3.2. **Batteries.** Provide maintenance free, spill proof, AGM batteries with the following minimum characteristics:

- 12 VDC,
- 80% allowable depth of discharge (DOD),
- rated for a minimum of 2,000 recharge cycles, and
- capacity rated at 77ºF, 100 hr. discharge rate.

Supply appropriate number of batteries to ensure the minimum total amp-hours meets or exceeds the value in Table 1 or 2, as described in the plans, when wired in parallel. Label, with a UV resistant system, the battery bank with maximum operating voltage, equalization voltage, and polarity.

Arrange the system components so that all battery terminals are guarded and adequate working space is provided per NEC 690.71(B)(2); 480.9.

Install current-limiting fuses on battery output circuits per NEC 690.71(C).

Provide overcurrent protection for the battery circuit conductors in conformance with NEC 690.9(A); 240.

Maximum system voltage is less than 600 V. Circuits over 150 V are to be protected so as to be only accessible to qualified persons, per NEC 690.7(C) and 690.7(D).

Install battery banks of greater than 48 V nominal in non-conductive cases. Conductive racks are permissible if no materials are located within 6 in. of the top of the battery case per NEC 690.71(D).

Provide series disconnects for battery strings over 48 V nominal per NEC 690.71(E).

Provide a maintenance disconnect for the grounded conductor of each string for battery systems over 48 V nominal. Make this disconnect accessible only to qualified persons per NEC 690.71(F).

Use battery interconnections with #2/0 AWG or larger flexible cables that are listed for hard-service use and are moisture resistant

3.3. **Panel Controller/Battery Charger.** Furnish and install maximum power point tracking (MPPT) controllers to ensure proper charging on the system battery bank. Provide an appropriate number of adequately sized MPPT controllers to meet or exceed the total charging amps shown in the system sizing tables. Provide MPPT controllers listed for the application, including UL 1741.

Provide MPPT controllers rated for the appropriate input and output voltages and currents needed for a fully functioning solar power system of the size called for in the plans.

Provide MPPT controllers with integrated battery overcharge and over-discharge protection.

Provide MPPT controllers with integrated temperature compensation.

Provide a blocking diode for reverse-current protection of the charging circuit. Reverse voltage rating of the blocking diode should be at least twice the open circuit voltage rating of the PV array to which it is fitted.

Incorporate thermal compensation in the charge control circuit to adjust the battery charge rate to variances in temperature with an adjustable voltage swing above and below the ambient set point as defined by the battery manufacturer. The battery float voltage calibration shall be at a voltage defined by the battery manufacturer at 25ºC ambient temperatures.

Provide light-emitting diodes (LED) or liquid crystal displays (LCD) to indicate solar panel charging and state of charge.

Provide surge protection for lightning and power surge protection.

Provide the controller with a low voltage disconnect (LVD) circuit. This circuit disconnects the battery bank when the battery voltage reaches a voltage that is deemed critical by the manufacturer of the battery. Provide an LED to indicate when the LVD circuit is active.

3.4. **Power Inverter.** Provide a stand-alone power inverter, with UL 1741 listing, to provide 120 V, 60 Hz, AC power output.

Provide true sine wave power with less than 3% total harmonic distortion.

Size the inverter to handle the largest load the system is expected to serve.

Provide overcurrent protection, disconnects, and ground fault protection.

Protect the inverter output circuit in accordance with NEC Article 240.

Label the inverter with the appropriate markings, including maximum input and output power ratings.

3.5. **Control Cabinet.** Manufacture the control cabinet of unpainted sheet aluminum with a thickness of at least 0.125 in. Size the cabinet to provide adequate space for the control electronics, desired number of batteries, and all co-located ITS field equipment shown on the plans, or as directed. Meet National Electrical Manufacturers Association (NEMA) standards publication 250-2003.

Provide a completely weatherproof cabinet to prevent the entry of water. All exterior seams are to be continuously welded for the cabinet and door. All exterior welds are to be smooth.

Provide the door with a full length stainless steel piano hinge. The hinge will be mounted so that it is not possible to remove it from the door or cabinet without first opening the door. Provide a double flanged cabinet door opening. Provide a closed cell neoprene gasket between the door and the cabinet to act as a permanent dust and weather resistant seal. Provide a minimum of 1/4 in. thick gasket. Tightly secure the door via a latching device which pulls the door snugly against the neoprene affixed gasket forming a weather tight seal. Provide cabinet with a Corbin style #2 lock with a keyhole cover as an integral part of the door and 2 keys. Provide cabinet with provisions to hold the door open at approximately 90º and 120º positions.

Provide louvers on each side of the cabinet to allow adequate cooling of the electronic components and to prevent the accumulation of gases. Provide screen vents that prevent entry of insects.

Provide an aluminum back panel in the lower compartment with a thickness of 0.125 in. Size the back panel to provide adequate space for the control electronics and terminal strip. Provide electronic components that can be easily installed or removed with simple hand tools.

Equip the cabinet with at least two shelves of a minimum thickness of 0.125 in, with a 1 in. x 3 in. cutout in the back of the shelves for cable run. Ensure that the shelves are capable of supporting design battery weight. Provide a rubber mat installed on each shelf that supports the batteries and two 1/8 in. drain holes located in the bottom of the cabinet at opposite corners. Provide a minimum of 2 in. of separation from the top of the battery posts to the bottom of the next shelf.

Equip the cabinet with all necessary mounting equipment and hardware. Configure the cabinet for pole mounting using two aluminum "U" channel mounting brackets with stainless steel reinforcing plates on the inside of the cabinet. Include a 0.25 in. aluminum reinforcing plate mounted in the bottom of the cabinet.

Cabinets meeting the ITS equipment cabinet specification are acceptable as long as they are sized to accommodate the entire system.

3.6. **Connectors and Harnesses**. Ensure all external connections are made by means of connectors. Key the connectors to prevent improper hookups. Color code and appropriately label with an UV resistant material all cables to and from the connectors on both ends.

Provide connecting harnesses of appropriate length and terminate with matching connectors for interconnection with the communications system equipment.

Plate all pins and mating connectors with a minimum of 20 microns of metallic native element gold (Au). Use heat shrink tubing for all solder-type connections to protect the connection from short circuiting.

Label with UV resistant methods to identify all assemblies with name, model number, serial number and any other pertinent information required to facilitate equipment maintenance.

Provide external waterproof connections that conform to International Electrotechnical Commission (IEC) specification 60529 Section 14.2.7, or most current version, for IP 66 or greater rating.

Provide connectors that are polarized, non-interchangeable, guarded, latching or locking, have “first-to-make/last-to-break” contact for the grounded conductor, and are either rated for interrupting current or require a tool to open per NEC 690.33.

Provide wiring connectors that are listed for the intended use and environment. Do not over tighten screws to terminals. Use the appropriate crimping tool for crimp-on terminals per NEC 110.14.

3.7. **Grounding.**

3.7.1. **Ungrounded Systems.** Include disconnects, overcurrent protection, and gound-fault protection. Provide equipment that is listed for use with ungrounded systems per NEC 690.35.

3.7.2. **Module Grounding Connectivity.** Provide module connections such that removal of a module does not interrupt a grounded conductor to another PV source circuit per NEC 620.4(C).

3.7.3. **Ground-Fault Protection.** Provide ground fault protection for grounded arrays per NEC 690.5.

3.7.4. **PV System Grounding.** Provide one grounded DC conductor for two-wire PV systems operating above 50 V per NEC 690.41; 250.4(A).

3.7.5. **Single Point.** Provide DC grounding at a single point on the PV output circuit per NEC 690.42.

3.7.6. **Equipment Grounding.** Ground non-current-carrying metal components, including module frames, mounting structures, equipment, conduit, and boxes per NEC 690.43.

3.7.7. **Equipment Grounding Conductors.** Route equipment conductors with PV circuit conductors per NEC 690.43.

3.7.8. **Equipment Grounding Conductor Size.** If the array has ground fault protection, size the grounding conductor according to NEC 250.122. If not, size the grounding conductor to handle at least twice the de-rated circuit conductor ampacity per NEC 690.45.

3.7.9. **Grounding Electrode Systems.** Ground the AC system according to NEC 250.50 through 250.60. Ground the DC system according to NEC 250.166 through 250.169, and NEC 690.47.

3.7.10. **Common Grounding.** If the system includes both AC and DC systems, bond the grounding electrodes together. Size the bonding conductor for the larger of the AC and DC requirements per NEC 690.47(C).

3.8. **Disconnects.** Provide disconnects to disconnect equipment (inverters, batteries, charge controllers, etc.) from all ungrounded conductors of all power sources per NEC 690.15.

For fuses that are energized from both directions, provide disconnects to independently disconnect the fuse from all sources of power.

Provide disconnects to open all ungrounded conductors which are readily accessible, externally operated, have ON/OFF indications, and have appropriate interrupt ratings. Manually operated switches and circuit breakers are allowed to fulfill these requirements per NEC 690.17.

3.9. **Mechanical Requirements.** Provide equipment that is modular in design such that it can be easily replaced in the field.

Clearly identify with UV resistant material each unit with name, model number, serial number and any other pertinent information required to facilitate equipment maintenance.

Coat all printed circuit boards with a clear-coat moisture and fungus resistant material (conformal coating).

3.10. **Environmental Requirements.** Ensure that equipment conforms to NEMA TS2-2003 (R2008), IEC 60529, and NEMA 250-2008, or most current version, for the following categories:

3.10.1. **Temperature and Humidity.** Provide equipment that conforms to NEMA TS2 Section 2.1.5.1, or most current version, and meets all the specified requirements during and after being subjected to any combination of the following conditions:

- ambient temperature range of -30 to 165°F,
- temperature shock not exceeding 30°F per hour,
- relative humidity of 0 to 100%,
- moisture condensation on all exterior surfaces caused by temperature changes, and
- Housing assemblies perform to stated specifications over an ambient temperature range of -30 to 165°F in direct sunlight and a humidity range of 0 to 100% condensing. Ensure that the system will operate without sustaining damage over a temperature range of -30 to 165°F.

3.10.2. **Vibration.** Provide equipment that conforms to NEMA TS2 Section 2.1.9 and Section 2.2.3, or most current version, and meets all the specified requirements during and after being subjected to a vibration of 5 Hz to 30 Hz up to 0.5 g applied in each of 3 mutually perpendicular planes for 30 min.

3.10.3. **Shock.** Provide equipment that conforms to NEMA TS2 Section 2.1.10 and Section 2.2.4, or most current version, and does not yield permanent mechanical deformation or any damage that renders the unit inoperable when subjected to a shock of 10 g applied in each of three mutually perpendicular planes for 30 min.

3.10.4. **Environmental Contaminants.** Provide equipment that conforms to IEC 60529 Section 14.2.6, or most current version for IP 66 or greater rating.

3.10.5. **External Icing.** Provide equipment that is tested to conform to NEMA 250-2003 Section 5.6, or most current version.

3.10.6. **Corrosion.** Provide equipment that is tested to conform to NEMA 250-2003 Section 5.10, or most current version, when located in coastal Districts. Coastal Districts are Beaumont (BMT), Corpus Christi (CRP), Houston (HOU), Pharr (PHR), and Yoakum (YKM).

4. CONSTRUCTION

Give particular care to the interconnection of all of the components and the cabling.

4.1. **General.** Furnish and install all materials, including support, calibration and test equipment, to ensure an operating and functional solar power system. Install power and data cables, power grounding and lightning suppression systems. Prior to beginning installation, inspect each site to verify suitability of the design for installation, grounding and lightning protection. Provide written documentation to the Engineer for approval prior to installation.

Configure and setup the solar power system to assure connection and electric power delivery to the field equipment as indicated in the plans. Locate and mount all equipment as detailed in the plans and as directed by the Engineer.

4.1.1. **Wiring.** Provide wiring that meets the requirements of the NEC. Provide wires that are cut to proper length before assembly. Provide cable slacks to facilitate removal and replacement of assemblies, panels, and modules. It is not acceptable to “double-back” wire to take up slack. Lace wires neatly with nylon lacing or plastic straps. Secure cables with clamps. Provide service loops at connections.

Size all conductors for a de-rated ampacity of at least 125% of the maximum currents calculated. De-rating factors include high ambient temperatures and number of conductors run together within a conduit or cable, per NEC 690.8(B), 310.15(B) and 310.16. Single-conductor cables in sizes 16 AWG and 18 AWG are permitted for module interconnections if they meet the ampacity requirements.

Protect all conductors operating at more than 30 V and installed in readily accessible locations with conduit, per NEC 690.31(A).

Provide conductors rated for 194ºF (90ºC) and wet service per NEC 690.31(B).

Run PV source- and output-circuit conductors separately from conductors of other systems per NEC 690.31(B).

Color code all wiring. Mark grounded conductors white or gray. Use green, green/yellow or bare grounding conductors, per NEC 310.12.

Provide strain relief or conduit on all conductors per NEC 300.4.

4.1.2. **Battery Storage.** Store batteries in a cabinet or underground in battery ground box, in accordance with the Department's electrical details.

4.1.3. **Poles.** Mount all PV units and cabinets on poles as shown on the plans in accordance with the ITS solar power system standards. Provide aluminum pedestal poles as shown on the plans for the height specified in accordance with Item 687, "Pedestal Pole Assemblies." Provide treated timber poles as shown on the plans for the height specified in accordance with Item 627, "Treated Timber Poles."

4.1.4. **System Optimization.** Optimize equipment alignment and settings at each site to provide a complete and operational system.

4.1.5. **Relocation.** Prior to removal of the existing solar power system, inspect the poles, cabinets, solar panels, batteries, MPPT charge controller, and cables where included, with a representative from the Department, and remove any solar power system equipment, associated mounting hardware, and cabling still attached to the pole or inside the cabinet prior to commencing work. Inspect the existing poles, cabinets, PV modules, batteries, and MPPT charge controllers in place, with a representative from the Department, and document any evidence of damage to the representative prior to removal.

Prior to removal of the existing solar power system, disconnect and isolate cables (power and communication) from the equipment. Remove and coil existing cabling to the nearest ITS ground box or as identified on the plans or as directed. Cover all exposed ends of the disconnected cables with a material, rated for long term use, to prevent dust and moisture contamination.

Carefully remove the solar power system components from the pole structures. Avoid damage or injury to surrounding objects or individuals.

Inspect the existing pole structures, with a representative from the Department, and document any evidence of structural stress cracks or fatigue prior to removal. Remove and deliver to the Department, existing pole structures that fail structural inspection.

Remove the existing pole structures in a manner acceptable to the Engineer. Use a method such that no undue overstress or damage will result to the structures or appurtenances attached.

Use a crane of sufficient capacity to remove the pole. Disconnect and relocate the existing pole structures from and to the foundations as shown on the plans in a manner acceptable to the Engineer.

When the poles are laid down, place them on timber cribbing so that they lie reasonably straight to prevent any damage or deterioration.

Maintain safe construction and operation practices at all times. Handle the poles in such a manner during removal so as to prevent damage to the pole's exterior finish. The Contractor will be responsible for any damage to poles.

Remove the existing concrete foundations to a depth of at least 2 ft. below finish grade with all steel cut off. Backfill the excavation with material equal in composition and density to the surrounding area, and replace any surfacing, such as asphalt pavement, concrete riprap or brick pavers, with like material to equivalent condition as approved by the Engineer.

Careful erection and aligning of the relocated pole structures shall be considered an essential feature of the installation of the pole structure.

Supply all new anchor bolts required for the installation of pole structures. Provide bolt dimensions and lengths as shown on the plans and as directed and in accordance with all requirements contained in this Item.

Separately package each component with appropriate protection to avoid damage during transit to the new location shown on the plans. Re-install each component and associated cabling to manufacturer specifications and tolerances. Orient and align the PV modules for optimal sun exposure. Install, calibrate, and program the charge controllers to manufacturer specifications. Ensure that the installation is completely operational and optimized at the new location shown on the plans.

4.1.6. **Removal.** Use established industry and utility safety practices when removing poles and assemblies located near overhead or underground facilities. Coordinate with the appropriate utility company before beginning work.

Inspect the poles, cabinets, solar panels, batteries, MPPT charge controller, and cables where included, with a representative from the Department, and remove any solar power system equipment, associated mounting hardware, and cabling still attached to the pole or inside the cabinet prior to commencing work. Inspect the existing poles, cabinets, solar panels, batteries, and MPPT charge controller in place, with a representative from the Department, and document any evidence of damage to the representative prior to removal.

Prior to removal of the existing solar power system, disconnect and isolate cables (power and communication) from the equipment. Remove and coil existing cabling to the nearest ITS ground box or as identified on the plans or as directed. Cover all exposed ends of the disconnected cables to prevent dust and moisture contamination.

Carefully remove the solar power system components from the pole structure. Avoid damage or injury to surrounding objects or individuals. Separately package each component with appropriate protection to avoid damage during transit. Deliver the equipment to an address to be supplied by the Department.

Carefully remove the pole from the foundation. Avoid damage or injury to surrounding objects or individuals. Separate the pole at the slip-fitted connections, if applicable. If the pole cannot be separated, transport the complete pole or partially separate the pole to make it transportable. Deliver the pole structure to an address to be supplied by the Department.

Remove the existing drill shaft foundations to a depth of 2 ft. below grade with all steel cut off. Backfill the excavation with material equal in composition and density to the surrounding area, and replace any surfacing, such as asphalt pavement, concrete riprap, or brick pavers, with like material to equivalent condition as approved by the Engineer.

4.2. **Testing.** The Engineer reserves the right to inspect and factory test any completed assemblies prior to delivery of the material to the project site. Correct any deviances from these specifications that are identified during testing prior to shipment of the assembly to the project site.

4.2.1. **New Installations.** Unless otherwise shown on the plans, perform the following tests on equipment supplied through this item.

4.2.1.1. **Test Procedures Documentation.** Provide 5 copies of the test procedures and blank data forms 30 days prior to testing for each test required on this project. Include the sequence of the tests in the procedures. The

Engineer will approve test procedures prior to submission of equipment for tests. Conduct all tests in accordance with the approved test procedures.

Record test data on the data forms, as well as quantitative results. No bid item measurement or payment will be made until the Engineer has verified the test results meet the minimum requirements of the specification. The data forms for all tests, except design approval tests, must be signed by an authorized representative of the Contractor.

Provide written notice to the Engineer within 48 hours of discovery of any testing discrepancy performed in testing by the contractor. Furnish data forms containing the acceptable range of expected results as well as the measured values.

4.2.1.2. **Design Approval Test.** Conduct a design approval test on randomly selected units from the prototype design manufacturing run. If only 1 design prototype is manufactured, perform this test on that unit. If supplying multiple types of the equipment, provide and test a sample of each type. Test all equipment and document compliance with IEC standards 61215, 61646, and 61730.

Certification from an independent testing laboratory of a successfully completed design approval test is acceptable. Ensure that the testing by this laboratory is performed in accordance with the requirements of this specification. Failure of independent tests to comply with the requirements of this specification will be grounds for rejection of any certification.

Provide a copy of the certification to the District in which this contract is executed. The data forms for the design approval tests must be signed by an authorized representative (company official) of the equipment manufacturer or by an authorized representative of an independent testing facility.

Notify the Engineer 10 working days before conducting this testing. The Department may witness all the tests. Perform the following tests:

4.2.1.2.1. **Temperature and Condensation.** Provide equipment which meets the performance requirements, specified in this Item, when subjected to the following conditions in the order specified below:

- stabilize the equipment at -30°F and test as specified in the most current version of the NEMA TS2 Standard - Sections 2.2.7.3, "Low-Temperature Low-Voltage Tests" and 2.2.7.4, "Low-Temperature High-Voltage Tests",
- allow the equipment to warm up to room temperature in an atmosphere having relative humidity of at least 40%. Operate the equipment for 2 hrs., while wet, without degradation or failure, and
- stabilize the equipment at 165°F and test as specified in the most current version of the NEMA TS2 Standard - Sections 2.2.7.5, "High-Temperature High Voltage Tests" and 2.2.7.6, "High-Temperature Low-Voltage Tests".

4.2.1.2.2. **Relative Humidity.** Provide equipment meeting the performance requirements, specified in this Item, within 30 min. of being subjected to a temperature of 165°F and a relative humidity of 18% for 48 hr.

4.2.1.2.3. **Vibration.** Provide equipment that shows no degradation of mechanical structure, soldered components, or plug-in components and operates in accordance with the manufacturer's equipment specifications after being subjected to the vibration tests as specified in the most current version of the NEMA TS2 Standard - Section 2.2.8, "Vibration Test".

4.2.1.2.4. **Electrical Insulation Resistance.** Test the insulation of each unit as follows:

- apply up to 1000 V maximum system voltage to the panel, and
- measure at least 40 mega-ohms of resistance between the frame and ground for every square meter of panel.

4.2.1.2.5. **Wet Leakage Current.**

- submerse the module in water, except the cable entries,
- apply a test voltage between the shorted output connectors and the water bath solution up to the max system voltage for 2 min., and
- provide resistance at least 40 mega-ohms per square meter of module.

4.2.1.2.6. **Bypass Diode Test.**

- apply a thermocouple to the diode body,
- heat the module to 167ºF (75ºC), and
- apply a reverse current equal to the short circuit for 1 hr.

4.2.1.2.7. **Maximum Power Degradation.** Test Pmax degradation of each PV module as follows:

- pre-condition each module by exposing them to a total of 0.51 kWh per square foot (5.5 kWh per square meter),
- apply irradiance of 91.8 W per square foot (1,000 W per square meter) at 77ºF (25ºC) at air mass 1.5,
- check Pmax, and
- ensure that Pmax degraded is at least 95% of the labeled rating.

4.2.1.2.8. **Thermal Cycling (TC200).** Test each PV module for 200 Cycles per IEC 61215

- heat PV modules to 77ºF (25ºC),
- inject a current within 2% of the current measured at peak power, and
- cycle temperatures per IEC standard 61646.

4.2.1.2.9. **Humidity-Freeze Test.** Conduct this test per IEC 61646.

4.2.1.2.10. **Damp-Heat (DH1000).** Test each PV module for 1000 hr. under the following conditions:

- 185 ± 3.6ºF (85 ± 2ºC) PV temperature, and
- relative humidity of 85% ± 5%.

4.2.1.2.11. **Mechanical Load Test.** Test the ability of the PV module to withstand wind, snow, static, or ice loads as follows:

- mount the module per manufacturer instructions,
- apply 0.215 psi (equivalent wind load at 110 mph) for 1 hour on each face of the module,
- increase pressure to 0.484 psi for snow and ice,
- no intermittent open circuits permitted during test, and
- visually inspect for defects.

4.2.1.2.12. **Hail Impact Resistance.** Use a 2 in. diameter steel ball weighing 1.18 lb., dropped from a height of 51 in. onto the center of the solar panel face.

4.2.1.3. **Demonstration Test.** Conduct a demonstration test on all major components at an approved Contractor facility. The Contractor may submit procedures and results from previous contracts in the same District as this contract, provided the materials and equipment are identical. Provide previous procedures and results that are, at most, 5 years old. Notify the Engineer 10 working days before conducting this testing. The Department may witness all the tests. Perform the following tests:

4.2.1.3.1. **Examination of Product.** Examine each unit carefully to verify that the materials, design, construction, markings and workmanship comply with the requirements of this Item.

4.2.1.3.2. **Continuity Tests.** Check the electrical continuity of the wiring to verify conformance with the applicable requirements in this item.

4.2.1.3.3. **Operational Test.** Operate each unit for at least 15 min. to permit equipment temperature stabilization and an adequate number of performance characteristics to ensure compliance with the requirements of this Item. At a minimum, test the following measured values against design assumptions:

- charging voltage at charge controller,
- output current at charge controller,
- output voltage at solar array,
- output voltage at battery bank, and
- solar array disconnect switch functionality.

With a fully charged battery bank, use the toggle switch to disconnect the solar panel array. Allow the system to run without solar power for 5 days. Measure the battery bank depth of discharge at the end of the 5 day test. Ensure that no more than 80% of full capacity has been discharged.

With the battery bank discharged to an 80% depth of discharge, connect the solar array on a sunny day. A sunny day is defined as daylight full sun for a period of at least 5 hrs. At the end of the day, test battery bank charge. Ensure that the battery bank is at full charge at the end of the day.

4.2.1.4. **Field Acceptance Test.** Following completion of equipment installation and operational optimization, submit an acceptance test plan to District for review and approval. During the official acceptance testing, provide the technical staff to conduct the measurements and adjustments called for in the testing. District will participate in the testing as the official test witness. Each page of the acceptance test document will provide for data recording of the test results, and the name of Contractor's representative conducting the test as well as a suitable field for the test date and signature of District test witness. Upon District approval of the test plan and the test schedule, the acceptance testing may begin.

Conduct a field acceptance test for each unit after installation as required by the Engineer in order to demonstrate compliance with the functional requirements with this Item. Exercise all stand-alone (non-network) functional operations. Provide a factory-certified representative for installation and testing of the equipment. Notify the Engineer 5 working days before conducting this test. The field acceptance test will at least consist of the following:

4.2.1.4.1. **Visual Inspection.** Conduct a visual inspection of all PV modules to ensure that none of the following are present:

- broken, cracked, or torn external surfaces, including superstrates, substrates, frames and junction boxes, or
- bent or misaligned external surfaces, including superstrates, substrates, frames, and junction boxes to the extent that the installation or operation of the module would be impaired, or
- a crack in a cell the propagation of which could remove more than 10% of that cell's area from the electrical circuit of the module, or
- bubbles or delaminations forming a continuous path between any part of the electrical circuit and the edge of the module, or
- loss of mechanical integrity, to the extent that the installation or operation of the module would be impaired, or
- module markings (label) are no longer attached, or the information is unreadable.

Conduct a visual inspection of the overall installation to ensure the following:

- equipment is installed and used in accordance with the plans and manufacturer’s instructions,
- site drawings include descriptions and locations of major components,
- electrical diagram includes component interconnects, conductor types and sizes, conduit types and sizes, disconnects, and point of interconnection,
- appropriate conductors and wiring methods are used,
- all PV conductors are routed through their own conduits, independent of conductors for other systems, and

- junction boxes are of appropriate type and size and allow the conductors within to be accessible.

4.2.1.4.2. **Physical Construction.** Verify physical construction is completed in accordance with the plans and specification.

4.2.1.4.3. **Electrical Connections.** Verify that all connectors for grounding, surge suppression, and electrical distribution are tightened correctly and are quality connectors. Verify the following:

- all power supplies and circuits are operating under the proper voltages,
- all power and communications cables are terminated correctly, secured inside the cabinet, and fitted with appropriate connectors,
- connectors are polarized, non-interchangeable, guarded, latching or locking, and have "first-to-make/last-to-break" contact for grounded conductor,
- wiring connectors are listed for the intended use and environment. Screw terminals are tightened to recommended torque. Crimp-on terminals are installed with appropriate crimping tool,
- grounded conductors are marked white or gray and grounding conductors are green, green/yellow, or bare,
- battery interconnections are made with #2/0 AWG or larger flexible cables that are listed for hard-service use and are moisture resistant, and
- current-limiting fuses are installed on battery output circuits.

4.2.1.4.4. **Grounding.** Field test equipment grounding for all ITS solar power system equipment installed in the field and provide written documentation to the engineer. Where earth ground resistance values exceed 5 ohms, develop mitigation measures for consideration. Once mitigation measures are installed, re-test earth ground and update the documentation. Ensure that grounded conductors are marked white or gray and grounding conductors are green, green/yellow, or bare.

4.2.1.5. **Final Acceptance Test.** Following completion of the demonstration test and field acceptance Test for all subsystems, provide completed data forms containing all of the data recorded, including quantitative results for all tests, a set of "as built" working drawings, and a written request to begin a data communication and final acceptance test. Provide "as built" working drawings indicating the actual material, equipment, connections, and construction of the various subsystem components. In addition, indicate the actual location that the components were installed, providing either GPS coordinates or dimensions to other fixed objects on the plans. For pole mounted solar arrays, provide an elevation view showing pole height, location of the panels on the pole, mounting details, and orientation or azimuth of the panels.

The project will not be accepted, notwithstanding other provisions in the Contract, until the system, inclusive of all subsystems, has operated satisfactorily for a period of 90 days and in full compliance with the plans and specifications after approval of all submitted test results and reports.

4.2.1.6. **Consequences of Test Failure.** If a unit fails a test, submit a report describing the root cause of the failure and the actions taken to remedy the situation prior to modification or replacement of the unit. If a unit requires modification, correct the fault and then repeat the test until successfully completed. Correct minor discrepancies within 30 days of written notice to the Engineer. If a unit requires replacement, provide a new unit and then repeat the test until successfully completed. Malfunctions that will substantially delay receipt and acceptance of the unit will be sufficient cause for rejection of the unit.

Failure to satisfy the requirements of any test is considered a defect and the equipment is subject to rejection by the Engineer. The rejected equipment may be offered again for retest provided all noncompliance has been corrected. Multiple failures are sufficient reason for complete rejection.

If a failure pattern develops in similar units within the system, implement corrective measures, including modification or replacement of units, to all similar units within the system as directed. Perform the corrective measures without additional cost or extension of the contract period.

4.2.1.6.1. **Consequences of Design Approval Test Failure.** If the equipment fails the design approval test, correct the fault within 30 days and repeat the design approval test until successfully completed.

4.2.1.6.2. **Consequences of Demonstration Test Failure.** If the equipment fails the demonstration test, correct the fault within 30 days and repeat the demonstration test until successfully completed.

4.2.1.6.3. **Consequences of Field Acceptance Test Failure.** If the equipment fails the field acceptance test, correct the fault within 30 days and repeat the field acceptance test until successfully completed.

4.2.1.6.4. **Consequences of Final Acceptance Test Failure.** If a defect within the system is detected during the final acceptance test, document and correct the source of failure within 30 days. Once corrective measures are taken, monitor the point of failure until a 30 consecutive day period free of defects is achieved.

If after completion of the initial test period, the system downtime exceeds 72 hr. or individual points of failure have not operated for 30 consecutive days free of defects, extend the test period by an amount of time equal to the greater of the downtime in excess of 72 hr. or the number of days required to complete the performance requirement of the individual point of failure.

4.2.2. **Relocation and Removal.**

4.2.2.1. **Pre-Test.** The Contractor will prepare a pre-test report for approval by the Engineer. Conduct performance testing prior to removal of solar power system. Test all functional operations of the equipment in the presence of representatives of the Contractor and the Department. Ensure that both representatives sign the test report indicating that the equipment has passed or failed each function. Once removed, the equipment becomes the responsibility of the Contractor until accepted by the Department. Compare test data prior to removal and test data after installation. The performance test results after relocation must be equal to or better than the test results prior to removal. Repair or replace those components within the system which failed after relocation but which passed prior to removal, at no cost to the Department.

4.2.2.2. **Post Test.** Testing of solar power system is for the purpose of relieving the Contractor of maintenance of the system. The Contractor will be relieved of the responsibility for maintenance of the system in accordance with Item 7, “Legal Relations and Responsibilities”, after all tests conducted in the pre-test have passed.

4.3. **Documentation.** Submit a system report detailing the PV array, battery bank, charge controllers, and shop drawings prior to the installation of the solar power system to the Engineer for review and approval. Shop drawings to include, but not be limited to:

- details of the complete installation of the system and all components to be supplied,
- details of all connections between the solar panel power supply system components,
- cabinet layout diagrams depicting the arrangement of all equipment inside the cabinets,
- instruction sheets and wiring diagrams for the equipment to be installed, and
- the manufacturer specifications and catalog cuts and parts lists.

Provide technical operators manuals for all equipment, including the PV modules, charging controller, and batteries.

Submit shop drawings, signed, sealed, and dated by a registered professional engineer in Texas showing the fabrication and erection details for each support, including the cabinet and mounting details in accordance with Item 5, “Control of the Work.”

Provide at least 2 complete sets of operation and maintenance manuals in hard copy format and on a CD/DVD or removable flash drive that include the following:

- complete and accurate schematic diagrams,
- complete installation procedures,
- complete performance specifications (functional, electrical, mechanical and environmental) on the unit,

- complete parts list including names of vendors for parts not identified by universal part number such as JEDEC, RETMA, or EIA,
- pictorial of component layout,
- complete maintenance and trouble-shooting procedures,
- complete stage-by-stage explanation of circuit operation,
- recovery procedures for malfunction, and
- instructions for gathering maintenance assistance from manufacturer.

Provide the Department with certification documentation verifying conformance with environmental and testing requirements contained in the special specification. Certifications may be provided by the manufacturer or through independent labs.

4.4. **Warranty.** Warrant the equipment against defects and failure in design, materials, and workmanship for at least 3 years or in accordance with the manufacturer's standard warranty if that warranty period is greater. The start date of the manufacturer's standard warranty will begin after the equipment has successfully passed all tests contained in the final acceptance test plan. Any equipment with less than 90% of its warranty remaining at the completion of the final acceptance test will not be accepted by the Department. Guarantee that equipment furnished and installed for this project performs according to the manufacturer's published specifications. Assign to the Department, all manufacturer's normal warranties or guarantees on all electronic, electrical, and mechanical equipment, materials, technical data, and products furnished for and installed on the project.

Repair or replace any malfunctioning equipment at the Contractor's expense prior to beginning the final acceptance test plan.

Repair or replace defective equipment during the warranty period at no cost to the Department. Any replaced units will inherit the remainder of the failed unit's warranty period.

Return all items sent to a factory authorized repair depot (in the United States) within 2 weeks of the date of receipt at the facility. Under the warranty, provide shipping free of charge both to and from the repair site.

For each component from the designated depot repair site, issue a warranty certificate indicating the start and end dates of the warranty. Supply the certificate at the conclusion of the Solar Panel Power System Acceptance Test or the end of the construction of the project, whichever comes last and set the end date for at least 2 years after that point. Name the District as the recipient of the service. Ensure that District has the right to transfer this service to other private parties who may be contracted to perform overall maintenance of the facility.

Furnish replacement parts and all equipment, with transportation prepaid, within 10 days of notification of failure by the Department.

During the warranty period, provide free technical support from the supplier. This support is to be free of charge, offered within 4 hours of request, and provided by factory certified personnel or factory certified installers of the equipment.

Provide ongoing software and firmware updates during the warranty period, free of charge. Any updates must be tested and approved by the Department prior to installation.

Maintain an inventory of parts to support maintenance and repair of all equipment.

5. MEASUREMENT

This Item will be measured by each ITS solar power system furnished, installed, relocated, or removed.

6. PAYMENT

6.1. **Furnish and Install.** The work performed and materials furnished in accordance with this Item and measured as provided for under "Measurement" will be paid for at the unit price bid for “SPS-INS” of the total system load (in Watts), the total solar panel (in Watts), the total battery (in amp hr) capacity, number of charge controllers with amperage capacity (Amps), and cabinet installation type**.** This price is full compensation for making fully operational a solar power system; all cabinets, treated timber poles, connectors and mounting assemblies, hardware, cables and connectors; and all testing, training, software, equipment, labor, materials, tools, and incidentals. Where the cabinet type is an ITS pole mounted cabinet, the cabinet will be paid for separately in accordance with “ITS Pole with Cabinet.”

New drilled shaft foundations will be paid for in accordance with Item 416, "Drilled Shaft Foundations."

New conduit will be paid for in accordance with Item 618, "Conduit."

Type Battery ground boxes will be paid for in accordance with Item 624, “Ground Boxes.”

Treated timber poles will be paid for in accordance with Item 627, “Treated Timber Poles.”

New pedestal poles will be paid for in accordance with Item 687 “Pedestal Pole Assemblies.”

New ITS poles with cabinets will be paid for in accordance with “ITS Pole with Cabinet.”

6.2. **Relocate.** The work performed and materials furnished in accordance with this Item and measured as provided for under "Measurement" will be paid for at the unit price bid for “SPS-REL” of the total system load (in Watts), the total solar panel (in Watts), the total battery (in amp hr) capacity, number of charge controllers with amperage capacity (Amps), and cabinet installation type. This price is full compensation for relocating and making fully operational an existing solar power system; and all testing, training, software, equipment, labor, materials, tools, and incidentals. Removal of existing foundations will be paid for under this item.

New drilled shaft foundations will be paid for in accordance with Item 416, "Drilled Shaft Foundations."

New conduit will be paid for in accordance with Item 618, "Conduit."

Type Battery ground boxes will be paid for in accordance with Item 624, “Ground Boxes.”

Treated timber poles will be paid for in accordance with Item 627, “Treated Timber Poles.”

New pedestal poles will be paid for in accordance with Item 687 “Pedestal Pole Assemblies.”

New ITS poles with cabinets will be paid for in accordance with “ITS Pole with Cabinet.”

6.3. **Remove.** The work performed and materials furnished in accordance with this Item and measured as provided for under "Measurement" will be paid for at the unit price bid for “SPS-REM” of the total system load (in Watts), the total solar panel (in Watts), the total battery (in amp hr) capacity, number of charge controllers with amperage capacity (Amps), and cabinet installation type. This price is full compensation for removing an existing solar power system; and all testing, training, software, equipment, labor, materials, tools, and incidentals. Removal of existing foundations will be paid for under this item.