

**PERFORMANCE SPECIFICATION  
FOR  
SOLAR PHOTOVOLTAIC POWER SYSTEM**

**prepared for**



**by**

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## **PART 1 - GENERAL**

### **1.1 Scope**

- .1 These specifications cover the procurement of design, equipment, hardware, documentation, labour and supervision required for the installation of grid-connected PV systems with a peak power rating of 2.5 kW up to 10 kW, as part of the Solar Schools project of the SolarBC Program.
- .2 The PV system described in this document shall be of the grid-connected type and shall not include battery/backup storage or secondary electrical generation devices. PV system shall feed AC power into the local services when solar energy is available and shall immediately disconnect from the grid upon loss of grid power to the service as per IEEE and local utility regulations.
- .3 One qualified Contractor will be selected to provide all labour, supervision, equipment, tools, materials and incidentals necessary to design, install, test and commission the complete solar photovoltaic system. The system shall operate in conjunction with the building's electrical system and be integrated with the school's building automation system (where applicable).
- .4 The Contractor shall be responsible for ensuring that the products provided will work together. The Contractor shall ensure products are installed correctly.

### **1.2 Submittals**

- .1 Manufacturer's description and technical data, such as performance curves, and product specification sheets,
- .2 Mechanical/structural drawings showing details of the array mounting rack, and layout of the array as affixed to the building envelope (such as rooftop, wall, or other attachment structure) or building site (ground or pole).
- .3 Electrical single-line drawing showing all major field-installed electrical components, wire identification and sizing.
- .4 Any shop drawings shall consist of 'items' that are necessary for the selection and installation of solar equipment and associated equipment and for wiring, and related foundations. Such 'items' can include illustrations, schedules, performance charts, instructions, brochures, diagrams, and drawings. Shop drawings for each requested item will be submitted prior to installation of that component.
- .5 Any CAD drawings shall be submitted as PDF, CAD, .DWG, or .DXF versions or as per Owner's specific requirements and shall be provided on optical disk or as per Owner's specific requirements.
- .6 All drawings shall be neat, clear and well arranged.
- .7 When manufacturers' cut sheets apply to a product series rather than a specific product, clearly indicate the data specifically applicable to this project.
- .8 Each submitted piece of literature and drawing shall clearly reference the relevant equipment and/or system.
- .9 General catalogues are not acceptable as product data sheets.
- .10 Schedules
  - .1 ***Within \_\_\_\_\_ weeks after award, unless otherwise specified, submit the following:***
    - .1 Schedule of all equipment required for the work delineated herein;
    - .2 Complete shop drawing showing the exact system layout including all components and accessories being provided or required for operation;

- .3 Details on the proposed interconnection of the PV system with the building's power distribution system;
- .4 Provide product data submittals.
- .2 **Submit design and the Project Record Documents to the Owner for approval prior to start of installation.**
- .3 **Within \_\_\_\_\_ weeks of contract award, provide a schedule of the work indicating the following:**
  - .1 Intended sequence of work items;
  - .2 Start dates of individual work items;
  - .3 Duration of individual work items;
  - .4 Planned delivery dates for major material and equipment and expected lead times;
  - .5 Milestones indicating possible restraints on work by other trades or situations.
- .4 **Provide regular written status reports indicating work completed, revisions to expected delivery dates, and updated project schedule as required by the Owner.**
- .11 Upon completion of installation, submit record (as-built) documents as follows.
  - .1 Project Record Drawings shall be as-built versions of the submittal shop drawings.
  - .2 Keep accurate daily records of all deviations in work from the original design by clearly marking up and noting them on the approved design drawings.
  - .3 Clearly indicate on the drawings the actual condition of the installed PV system at the time of final acceptance.
  - .4 Certify the accuracy of each drawing by endorsing and signing each marked drawing.
  - .5 When work is complete, furnish one (1) complete "Record" set of marked drawings.
- .12 Testing and Commissioning Reports and Checklists
  - .1 Include completed versions of all reports and checklists.
- .13 Inspection Reports
  - .1 **Furnish all certificates necessary to evidence that the work installed conforms to all applicable laws and regulations of all Authorities Having Jurisdiction.**
- .14 Operating and Maintenance Manuals
  - .1 **Submit manuals that detail the step-by-step procedures required for system start-up, operation, and shutdown. Include in the manuals the manufacturer's name, model number, service manual, parts list, and brief descriptions of all equipment and their basic operating features. List routine maintenance procedures, possible breakdowns and repairs, recommended spare parts, troubleshooting guides, wiring and equipment layout, and simplified wiring and control diagrams.**
  - .2 **A suggested format for the Operation and Maintenance Manual is provided as an Appendix**

### 1.3 Quality Assurance

- .1 The PV system Design and Installation Contractor shall:
  - .1 ***Employ personnel with demonstrated reputable experience in multi-module grid-connected PV system design.***
  - .2 ***Be a licensed electrical contractor in good standing, or shall maintain a contractual relationship with a licensed electrical contractor in good standing for the duration of the installation, who will carry the responsibility for the installation.***
- .2 This system shall be installed by a team with demonstrated experience in electrical and PV system supply and installation.
- .3 The Contractor shall designate a NABCEP certified Photovoltaic Installer, **or a person who meets the eligibility requirements for NABCEP certification**, as site supervisor.

### 1.4 Permits

- .1 The Owner is responsible for obtaining the development permit, if required.
- .2 The Installation Contractor is responsible for any electrical and building permits and their inspection.

### 1.5 Codes And Standards

- .1 All work, materials, equipment, installation and wiring shall comply with acceptable industry specifications and standards for performance, reliability, and compatibility and be executed in strict adherence to the rules and regulations of all codes and ordinances of the local, provincial, and national authorities. Such codes, when more restrictive, shall take precedence over these plans and specifications.
- .2 As a minimum, all work and products shall comply with the regulations of the following authoritative bodies, the codes in effect 30 days after receipt of bids, and any other Authorities Having Jurisdiction:
  - .1 ***Fire Marshall***
  - .2 ***British Columbia Electrical Code***
  - .3 ***Local Building By-Laws***
  - .4 ***Worker's Compensation Board***
  - .5 ***Canadian Standards Association***
  - .6 ***Pollution Control Board***
  - .7 ***British Columbia Building Code***
  - .8 ***Underwriters' Laboratories of Canada***
- .3 The system design, equipment and installation shall comply with the requirements of one of the following documents:
  - .1 ***BC Hydro, NET METERING INTERCONNECTION REQUIREMENTS, 50 KW & BELOW, dated 22 October 2003 or later; or***
  - .2 ***Fortis BC, GUIDELINES FOR OPERATING, METERING, AND PROTECTIVE RELAYING FOR NET METERED SYSTEMS UP TO 50 kW AND BELOW 750 VOLTS; or***
  - .3 ***Nelson Hydro, GUIDELINES FOR OPERATING, METERING and PROTECTIVE RELAYING FOR CO-GENERATORS AND SMALL POWER PRODUCERS, dated January 2, 2003 or later.***

- .4 Where materials or equipment are specified to comply with requirements of a code or standard, submit proof of such compliance upon request from the Owner.

#### 1.6 Regulatory Approvals

- .1 The Contractor is responsible for obtaining regulatory approvals to permit the interconnection of the PV system into the local Wires Service Provider's electrical distribution system.

#### 1.7 Location of Photovoltaic Array

- .1 The location of the array of solar PV modules will be as designated by the Owner.
- .2 The Owner will decide whether the array is installed on a building's roof or wall, on the ground, or another structure such as an overhang, canopy, awning, entranceway, or parking lot. The building may be new or existing.
- .3 All AC electrical components will be installed in a room or rooms inside a building, the location of which will be decided by the Owner.

#### 1.8 Design Requirements

Design the complete PV system and select all its electrical components including PV modules, DC disconnect, grid-dependent inverter, AC branch circuit breaker, and any PV module by-pass diodes, DC over-current protection, PV combiner boxes, AC disconnect, and surge suppression device required.

The following design requirements apply:

- .1 Design the system to maximise its benefits to its Owner.
- .2 Design and select PV system components according to Generally Accepted PV Design principles.
- .3 Design and select the wiring, cabling, including PV module interconnections, photovoltaic source circuit, photovoltaic output circuit, PCU output circuit, equipment bonding, and equipment and system grounding.
- .4 Select an appropriate PV module mounting rack. Ensure area of array attachment structure is capable of handling the array size.
- .5 Design penetration of roof, wall or other attachment structure, or ground piles as appropriate.
- .6 Include a monitoring system to measure and record system performance parameters.
- .7 Include all the equipment design and selection necessary to provide a functional installed system.
- .8 Design the system for the local solar radiation and temperature conditions.
  - .1 *If these data are not available for that location, then the closest location in which these data have been recorded is acceptable.*
  - .2 *All equipment located outdoors shall be rated and warranted to withstand and operate under these conditions.*
- .9 System electrical drawings shall be sealed by a professional electrical engineer licensed in the province of BC, **if required by the local authority having jurisdiction.**
- .10 Provide an estimate of the annual and monthly system electricity production along with a description of the Modeling method or the calculations upon which the estimate is based and de-rate factors therein.
- .11 Select a PV module mounting system for the appropriate array-to-building attachment structure.

- .12 If the PV array is to be mounted on the ground or on a pole, select an appropriate mounting rack and ground pile system.
  - .13 System structural drawings shall be sealed by a professional structural engineer licensed in the province of BC, **if required by the local authority having jurisdiction.**
- 1.9 Building Envelope Penetration**
- .1 Verify that the array attachment structure is capable of handling additional weight of array. Augment structure as necessary.
  - .2 All building envelope penetrations shall be acceptable to the Owner.
  - .3 Any building envelope penetration shall be designed to prevent moisture ingress into the envelope from the exterior and vapour diffusion into the envelope from the interior.
  - .4 If the array is to be roof mounted:
    - .1 ***Co-ordinate with the Owner and local roofing contractors' association regarding any roof warranty requirements.***
    - .2 ***If required by the Owner, the roof penetration design shall qualify for warranty by the local roofing contractors' association.***
- 1.10 Design Warranty**
- .1 Warrant all design work as follows for the duration of the project until handover to the Owner:
    - .1 ***Accuracy of design sizing***
    - .2 ***Appropriateness of component selection***
  - .2 Should design issues arise, provide design revisions during the warranty period at no additional cost to the Owner.

## **PART 2 - PRODUCTS**

### **2.1 Specifications**

- .1 The description, characteristics, and requirements of products and materials to be used shall be in accordance with qualifying conditions established in the components specification sheets.

### **2.2 Identical Items**

- .1 Items of the same classification shall be identical, including equipment, assemblies, parts, and components.

### **2.3 Standard Products**

- .1 Use new products currently under manufacture that have been applied in similar installations for a minimum of two years.
- .2 Do not use this installation as a test site for any new products unless explicitly approved by Owner in writing.

### **2.4 Nameplates**

- .1 All component parts of each item of equipment or device shall bear the manufacturer's nameplate, giving the name of manufacturer, description, size, type, serial or model number, electrical characteristics, etc., in order to facilitate maintenance or replacement. The nameplate of a subcontractor or distributor will not be acceptable.
- .2 Nameplates shall be provided for:
  - .1 ***Solar PV modules***
  - .2 ***Combiners (if required)***
  - .3 ***DC disconnects***
  - .4 ***Inverters***
  - .5 ***AC disconnects***

### **2.5 Operating Condition Ratings**

- .1 All equipment and materials located outdoors shall be resistant to sunlight, temperature, humidity and other weather conditions to which they are exposed.
- .2 All electrical equipment and products shall have appropriate voltage, current, and temperature ratings for the intended application.

### **2.6 Materials**

- .1 This sub-section contains the minimum recommended materials specifications.
- .2 Dissimilar metals (such as steel and aluminum) shall not be used in direct contact with one another.
  - .1 ***Separate all steel/aluminum connections with neoprene gaskets. Epoxy coat all steel brackets (use Amerlock 400 high solids epoxy and Amercoat 385 topcoat by Amercoat Canada or approved equal).***
- .3 Aluminum shall not be placed in direct contact with concrete materials.
- .4 Only high quality fasteners are to be used (stainless steel is preferred).
- .5 Structural members should be either:
  - .1 ***Hot dip galvanized steel per ASTM A 123***
  - .2 ***Corrosion resistant aluminum, 6061 or 6063***

.3 ***Stainless steel (particularly for corrosive marine environments)***

2.7 Acceptable PV Modules

- .1 PV modules shall meet or exceed the requirements of:
  - .1 ***IEC 61215 – "Crystalline Silicon Terrestrial Photovoltaic Modules - Design Qualification and Type Approval" (if crystalline modules are selected), or equivalent; and***
  - .2 ***ULC/ORD C1703-01 – "Flat Plate Photovoltaic Modules and Panel", "IEC 61730 – Photovoltaic Module Safety Requirements (Part 1 and 2)", or equivalent.***
- .2 PV modules shall be framed, flat-plate, non-concentrating type.
- .3 The PV modules shall have the following certifications at the time of their delivery on site:
  - .1 ***Bear a mark as part of its nameplate or covering part of its nameplate certifying it to applicable Canadian standards. The certification mark shall be as allowed by BC Safety Authority Information Bulletin B-E3 071019 3 Approved Certification Marks for Electrical Products.***
- .3 Each PV module shall have one or more bypass diodes installed in the module junction box.
- .4 The same brand and model of PV module shall be used for each module in the array.
- .5 PV modules shall have a minimum 20-year pro-rated power performance warranty and a minimum 2-year product warranty for defects in material and workmanship.

2.8 Acceptable Grid-Dependent Inverters

- .1 The inverter's DC side shall:
  - .1 ***Be compatible with the PV system array output.***
  - .2 ***Be capable of completely automatic, continuous, unattended and stable operation over the range of voltages, currents, power levels and temperatures for the size, type and location of the array to which it is connected, including at start-up, synchronization and disconnect,***
  - .3 ***Employ maximum power point tracking technology (MPPT) technology.***
- .2 The inverter's AC side shall:
  - .1 ***Have a power factor of 1 without using external reactive power compensation.***
  - .2 ***Have an AC output voltage that is directly compatible to the building or site distribution voltage without the use of an external voltage transformer. Such voltage can be single-phase 120 VAC, single-phase 240 VAC, or single-phase or three-phase 208 VAC, for example.***
  - .3 ***Not require an external isolation transformer.***
  - .4 ***Be capable of operating in parallel with other inverters and the local electrical distribution system.***
  - .5 ***Employ built-in mechanisms that cause it to cease to energise its AC terminals due to conditions of over-voltage, under-voltage, over-frequency, under-frequency, and anti-islanding.***
- .3 The inverter shall:

- .1 ***Have a communication port capable of remote monitoring of inverter operation from a computer or from specialised monitoring equipment.***
- .2 ***Be fail-safe.***
- .3 ***Meet the requirements for a grid-connected inverter as specified by the Electrical Supply Authority.***
- .4 The inverter shall have the following certifications at the time of its delivery on site:
  - .1 ***Listed to all applicable CSA standards.***
  - .2 ***Compliant with Canadian Standards Association standard C22.2 No. 107.1, General Use Power Supplies, Clause 15, Utility-Interconnected Inverters.***
  - .3 ***Contain a mark on its label or documentation indicating that it meets the CSA performance standard C22.2 No. 107-01 for grid-connection.***
  - .4 ***Bear a mark as part of its nameplate or covering part of its nameplate certifying it to applicable Canadian standards. The certification mark shall be as allowed by BC Safety Authority Information Bulletin B-E3 071019 3 Approved Certification Marks for Electrical Products.***
  - .5 ***Notwithstanding BC Safety Authority Information Bulletin B-E3 071019 3, Special Inspection marks are not acceptable certification marks for the inverter.***
- .5 Multiple smaller inverters may be used instead of a larger single unit.
- .6 The inverter's operator interface shall consist of a multi-line LCD text display on the front. It shall have an automatic visual indicator showing whether the system is on-line or not.
- .7 The inverter shall have at least a five-year repair or replacement warranty from the manufacturer covering parts and labour, in cases of failure due to materials or workmanship. Warranty period shall start on the date of system acceptance.
- .8 Provide at no charge, any inverter firmware upgrades that become available during the warranty period, and that resolve known software deficiencies as identified by the Equipment Supply Contractor.
- .9 Inverters that require a battery bank or other energy storage means are not acceptable.

## 2.9 Acceptable Wiring

- .1 All wiring shall be listed to provincial electrical codes.
- .2 All wiring shall be new.
- .3 All insulated wire to be copper conductors.
- .4 Wiring shall be suitable for the location in which it is used and rated for the conditions in which it is installed.
- .5 Insulation rating on power wiring shall be 600 V.
- .6 All outdoor wiring shall be UV resistant, labelled as such, and listed for temperature rating of 90°C in wet locations.
- .7 In areas where the conductors may be subject to high temperatures such as in exposed conduit or mechanical rooms, the insulation rating shall be 90°C. In other areas, a 75°C insulation rating is acceptable.
- .8 Conductors 10 AWG and larger shall be stranded.

- .9 The use of any exposed conductors or cabling (excluding equipment bonding, and grounding conductor wiring) is not acceptable.
- .10 Total DC circuit wiring losses shall be limited to no more than 1%.
- .11 All DC and AC wiring connected to inverter must conform to requirements given by inverter manufacturer.
- .12 Total PCU (inverter) output circuit wiring losses shall be limited to ensure proper operation of the inverter under the conditions of use, and in no case shall be greater than 3%.
- .13 Grounding and bonding methods shall be according to Generally Accepted PV Design criteria, and the requirements of the British Columbia Electrical Code.

#### 2.10 Acceptable PV Module Mounting Rack

- .1 Mounting rack shall provide for each module to be individually removed for maintenance, repair, or replacement.
- .2 Mounting rack shall ensure that the bonding of all modules is not broken if a module is removed.
- .3 Mounting rack shall be appropriately designed for the array tilt angle, angle of attachment structure, space availability and wind and snow loading.
  - .1 **Mounting rack including installed modules, hardware and attachments shall:**
    - .1 Be structurally capable of withstanding the worst of the effects of 1.5 kPa wind pressure, or the effects of the design wind speed for the locality with a 1 in 50 year return period; and
    - .2 Comply with all existing local and national codes.
- .4 The PV module mounting rack shall allow the PV array to be installed such that the individual modules are uniformly spaced and in a single plane.

#### 2.11 Acceptable Monitoring Equipment

- .1 The monitoring systems shall provide access to operational and performance data of the Photovoltaic system via web-based interface and shall record and display at minimum:
  - .1 **Array voltage - VDC (V)**
  - .2 **Grid voltage - VAC (V)**
  - .3 **Array current - IDC (A)**
  - .4 **Grid current - AC (A)**
  - .5 **Array power - PDC (W)**
  - .6 **Grid power - PAC (W)**

#### 2.12 Acceptable PV Combiner and Array Combiner

- .1 A PV combiner or other junction box may be needed to connect Photovoltaic source circuits in parallel, and contain disconnecting means, over-current protection or blocking diodes.
- .2 Combiner to have a DC voltage and current rating appropriate to the Photovoltaic source and output circuits, where required.

#### 2.13 Acceptable DC Disconnect

- .1 DC disconnects to have a DC voltage and current rating appropriate to the Photovoltaic output circuit.

## **PART 3 - EXECUTION**

### **3.1 General Information**

- .1 This Section covers the installation and testing of equipment and hardware to provide a fully functional grid-connected solar photovoltaic (PV) system as per the design.

### **3.2 Wiring**

- .1 The visual appearance of all wiring shall be to satisfaction of the Owner.
- .2 All wiring shall meet the installation and product standards for the interior or exterior environment in which it is installed.
- .3 All DC wiring shall be installed in accordance with the British Columbia Electrical Code.
- .4 All communication wiring shall meet British Columbia Electrical Code Class 2 standards.
- .5 Wiring shall be continuous for each wiring run. Splices shall only be allowed in approved enclosures.
- .6 All wiring within enclosures shall be neatly bundled and anchored to permit easy access to devices and terminals.
- .7 Raceway must be installed in accordance with the British Columbia Electrical Code.
- .8 Outdoor raceways that are visible from the ground or raceways installed in finished areas shall be painted as required by the Owner.
- .9 All wire-to-equipment connections shall be made at a terminal block or terminal strip when supplied with the equipment.

### **3.3 Warranty on labour**

- .1 In addition to the product warranties required by section 2.7.5 and 2.8.7 of this document, furnish a written warranty on the entire PV system and all of its equipment, components, hardware, materials and labour stating that all work executed under this document will be free from defects of material and workmanship for a period of two years from the date of final system acceptance. Warranty shall cover any equipment, components or structures furnished here that are found to be defective under normal operating conditions and/or for their intended purpose.
- .2 This warranty shall provide for service at the site including the repair and/or replacement of components found to be defective during the warranty period.
- .3 The Contractor may include pass through warranties from the manufacturers of major system components and PV modules. However, it will be the responsibility of the Contractor to provide initial trouble shooting of the system and to obtain service/support by the manufacturers under their warranties during the period of this warranty.
- .4 PV system failures during the warranty period shall be adjusted, repaired, or replaced at no additional cost to the Owner.
- .5 The Contractor shall respond to the Owner's request for warranty service within 24 hours during normal business hours.
- .6 All work shall have a single warranty date, even when the Owner has received beneficial use due to an early system start-up.
- .7 This warranty shall start after 30 continuous days of trouble free operation of the PV system following written acceptance of the system by the Owner.

- .8 Provide at no charge, any inverter firmware upgrades that become available during the warranty period.
- .9 In default, Owner may have such work done and charge costs to Contractor.
- .10 This warranty covers faulty materials and/or workmanship only. All other causes for system malfunctions and/or failures, including, but not limited to, those caused by misuse, abuse, neglect, accident, riot, fire, vandalism; acts of nature such as floods, storms, earthquakes, or tornadoes; or other causes beyond the control of the Contractor, are excluded from this warranty.
- .11 This warranty is invalid if the system is modified in any way without the consent of the Contractor.

### 3.4 Supervision

- .1 Actively supervise the installation work and co-ordinate schedules and tasks of any Sub-Contractors.
- .2 Continually monitor the field installation for code compliance, compliance with these specifications, and quality of workmanship.

### 3.5 Safety Protection

- .1 Construct and maintain appropriate safety mechanisms for all Work.

### 3.6 Fire Protection

- .1 Provide as a minimum, one 5 lb (2.3 kg) extinguisher rated for Types A, B, and C fires with each work crew at all times when working within a building or on the roof or walls of a building.

### 3.7 Site Co-ordination

- .1 Solicit from the Owner a notification of any separate construction projects that will be running concurrently on the site.
- .2 Solicit from the Owner a decision of which Contractor's work will take priority.
- .3 Provide a technical briefing to the Facilities Manager to review installation procedures, safety, etc., prior to installation.
- .4 Where the Work will be installed in close proximity to, or will interfere with, work of other trades, assist in co-ordinating space and schedule to make a satisfactory complimentary arrangement.

### 3.8 General Workmanship

- .1 The quality of workmanship in the execution of this work shall be the finest and highest obtainable in the trade working with the materials specified. Workmanship shall be satisfactory to the Owner, and his/her decision as to acceptable quality is final.

### 3.9 Site Access

- .1 Make all arrangements to ensure that access to the work space is available for all equipment and work. Do all hoisting and rigging into place of all equipment and be responsible for any damages incurred.
- .2 Confirm with Facilities Manager the safest and best locations for access to the location where the PV system will be installed.

- .3 Avoid any extended blockage of driveways required for access to the building. Notify the Facilities Manager at least 48 hours in advance of any access interference and obtain approval before proceeding with interruptions.

### 3.10 Delivery

- .1 Contractor shall ensure that sufficient lead-time is given to prevent late delivery of equipment and materials and installation delay problems.

### 3.11 Handling and Storage

- .1 Store all equipment delivered to the job site under a roof or other weatherproof covering on blocks above the ground. Contractor is fully responsible for the storage and care of equipment and materials.
  - .1 **Protect PV modules during delivery, storage, and handling to comply with manufacturer's directions, and as required to prevent damage.**
    - .1 Minimise the risk from exposed fasteners, sharp edges, and potential damage to the modules or support structure.
    - .2 Ensure modules are always fastened to their shipping pallet or mounting rack to avoid them blowing off the roof.
    - .3 Do not install any scratched or damaged modules.
    - .4 Keep modules clean.
  - .2 **Store and protect all electronic components in a dry, dust free environment until time of installation.**
- .2 If any materials and/or equipment are found to be damaged or otherwise in poor condition when being installed, furnish and install new undamaged equipment at no cost to the Owner.

### 3.12 Installation – Building Envelope Penetrations

- .1 Any building envelope penetration shall be sealed to prevent moisture movement into the envelope from the exterior or the interior using industry-approved sealing methods according to standard building practices.
- .2 Install all roofing and building envelope penetrations and all connections to the roof and building envelope structure as per Project Record Drawings.
- .3 Use only as many attachment points and roof penetrations as necessary for structural loading. The number of attachment points and structural requirements of the roof must be specifically identified in the drawings.
- .4 If the PV array is to be roof mounted:
  - .1 **Before roof work is started, co-ordinate with the Owner regarding any roof warranty requirements.**
  - .2 **If required by the Owner, the roofing penetrations shall qualify for warranty by the local roofing contractors association.**
  - .3 **Seal roof penetrations to building code requirements. Including approved fire stops in all building envelope penetrations**
- .5 Properly size all wiring penetrations of the building envelope.

### 3.13 Field Testing – PV Modules

- .1 Upon receipt, visually check each PV module for signs of damage.

- .2 Field-test each PV module prior to installation to verify electrical integrity and specified performance.
    - .1 **Measure and record open circuit voltage ( $V_{oc}$ ) and short circuit current ( $I_{sc}$ ) and compare the results between modules or to manufacturers specifications to ensure modules are within manufacturers' specified tolerances.**
    - .2 **Estimate and record ambient air temperature and solar irradiance conditions.**
    - .3 **Complete the testing under constant solar irradiance and temperature conditions.**
    - .4 **In the event measurements are outside manufacturers' specified tolerances, deem the module defective.**
    - .5 **Defective modules are not to be installed.**
    - .6 **Submit a copy of all testing records to the Owner.**
- 3.14 Installation – PV Array**
- .1 Co-ordinate the PV array installation with building envelope penetration or groundwork.
  - .2 Confirm roof area or other installation site is capable of handling the designed array size with no overhanging edges except as per design.
  - .3 If roof mounted, verify that the roof is capable of handling additional weight of PV system. Augment roof structure as necessary.
  - .4 Install PV mounting rack and modules as per Project Record Documents and rack manufacturer assembly instructions.
  - .5 Adjust PV module position to achieve uniform spacing between modules.
  - .6 Ensure corrosion resistance and durability of all mechanical hardware.
- 3.15 Installation – Inverter**
- .1 The installed location of inverters shall not violate manufacturer's warranty provisions. Inverters shall be located in a space that complies with the inverter's ambient temperature operating requirements.
- 3.16 Installation – Wiring**
- .1 Install all wiring connections and terminations at PV modules and inverters in accordance with manufacturers' instructions.
  - .2 Label all circuits within combiner boxes and any terminal strips in junction boxes for polarity and string number (both positive and negative). Label all other wiring for polarity and/or phase.
- 3.17 Installation – System**
- .1 All drawings, component manuals (especially inverter manuals), are to be read and understood prior to installation.
  - .2 Comply with component manufacturer's instructions to provide a fully integrated and operational system. Ensure that all required and recommended clearances are maintained.
  - .3 Connect PV system to the building's electrical distribution system.
  - .4 Verify integrity of all wiring to ensure continuity and absence from electrical short circuits.

- .5 Ensure the installation meets local Electrical Supply Authority interconnection requirements.
- .6 Have final inspections completed by the Authority Having Jurisdiction (AHJ) and the Supply Authority (if required).
- .7 The PV System shall not be left operational without the permission from the local Supply Authority.
- .8 The Contractor shall notify the Owner in writing when the entire PV system is installed, and the preliminary field-testing is successfully completed.

### 3.18 Installation – Monitoring Equipment

- .1 Confirm before installation that the Owner has installed a suitable network communication cable, if required by the monitoring system, and that this cable is operational.
- .2 Install monitoring equipment, instrumentation and wiring according to manufacturers installation instructions.
- .3 Confirm that the monitoring equipment is operational.

### 3.19 Identification Of Components

- .4 Furnish and install permanent as-built drawings as per the Supply Authority.
- .5 Clearly identify all control devices (*i.e.*, circuit breakers, switches, AC and DC disconnects) as to their function and the equipment controlled.
- .6 Clearly identify inverters and the panel board they serve.
- .7 Furnish and install warning signs as per the requirements of the British Columbia Electrical Code and the Supply Authority.
- .8 All equipment labels and warning signs shall be permanently fastened engraved phenolic (lamacoid-type) legend plates with standard engraver's letter style, using a standard size appropriate for the application.

### 3.20 Field Testing - System

- .1 Field-test the PV array (or each PV string or sub-array when installed) in the presence of the Owner to verify electrical integrity and specified performance.
- .2 Measure the array (or each string or sub-array)  $V_{OC}$  and  $I_{SC}$  under sunny weather conditions. Estimate ambient air temperature and solar radiation conditions. Record and check for consistency with the module field-test measurements.
- .3 Test the 5-minute start up delay. Test the automatic shut down. Go through the start-up sequence.
- .4 Follow manufacturer's inverter commissioning procedure
- .5 Submit all field test results to the Owner for approval.
- .6 The Supply Authority may require that a representative be on-site at the time of the initial system turn on. Provide sufficient notice and co-ordinate work accordingly.
- .7 Correct all installation defects identified by the field testing.

### 3.21 Acceptance

- .1 The PV system is not accepted until the Owner provides a written statement of acceptance.
- .2 Acceptance of the system by Owner will only take place after any deficiencies identified by the commissioning tests are corrected, and the system operates successfully during a 30-day initial operating period.

- .3 At the end of the final start-up and testing, if equipment and systems are operating satisfactorily to the Owner, the Owner shall sign certificates stating that the PV system's operation has been tested and accepted in accordance with the terms of this specification.

### 3.22 Field Training

- .1 Provide a field-training course for operating and maintenance staff members after the system are functionally complete. Include in the training a discussion of the system design and layout and demonstrate routine operation, maintenance and troubleshooting procedures.

- End of Specification -

## Appendix

### Suggested format for PV system operating and maintenance manual

#### .1 CONTENTS

- .1 ***Front page to include project title plus "Solar PV System Operating and Maintenance Manual"***
- .2 ***Second page to include the names, addresses, phone and fax numbers and e-mail addresses of (as applicable):***
  - .1 The Owner
  - .2 The Consultant
  - .3 The Design Contractor
  - .4 The General Contractor
  - .5 The Equipment Supply Contractor
  - .6 The Installation Contractor
  - .7 Any Sub-Contractors, such as a roofing contractor, PV array installer
  - .8 Equipment servicing contacts
- .3 ***List of As-built Schematics***
  - .1 Site plan
  - .2 Electrical single- and triple-line drawings
- .4 ***System Description:***
  - .1 Clearly describe the system design and configuration.
  - .2 Clearly describe the operation of the PV system (how does it work), and explain the function of each sub-system (if any).
  - .3 Provide an overview of major system components (array, inverter, disconnects, over-current protection) and their connections.
- .5 ***Operators Manual:*<sup>1</sup>**
  - .1 Provide procedures for operating the PV system, verifying correct system operation, normal system start-up, normal shutdown, producing performance data, and changing inverter protection settings (if permitted).
  - .2 Provide a complete description of emergency shutdown and isolation procedures.
  - .3 Provide a complete description of start-up procedures for all major equipment, sub-systems and controls, including any alarm functions and power failure mode.
- .6 ***Maintenance Manual:***
  - .1 Provide maintenance procedures for servicing and maintaining complete system and individual components including:
    - .1 *All necessary ordinary maintenance, preventive maintenance, minor repair work, and projections for equipment replacement.*
    - .2 *Cleaning the array, if required.*

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<sup>1</sup> Referencing key specific page numbers in equipment manuals is acceptable where available.

- .3 *A schedule of tasks (inspection, cleaning, etc.), time between tasks, and task descriptions.*
- .4 *How to repair or replace hardware.*
- .5 *Preventing array shading due to the growth in foliage.*
- .2 Describe how to troubleshoot array and inverter problems, including:
  - .1 *Trouble-shooting sequences.*
  - .2 *The voltage and current expected at various access points to allow simple operational and troubleshooting checks.*
  - .3 *A list of checkpoints if system fails.*
- .3 Provide warning against hazards that could arise in the operation or maintenance of the system and fully describe the precautions that are to be taken to avoid these hazards.
- .4 Provide considerations for any future building renovations adjacent to the array to avoid potential damage or shading of the array.
- .5 Include a parts list giving a sufficient description of each part for ordering a replacement.
- .6 Provide two-page maintenance log for tracking planned and unplanned maintenance with columns for sequential entry #, date of entry, and entry description.
- .7 *List of Equipment Supply Contractors and warranties:***
  - .1 Provide complete list of Equipment Supply Contractors, including address and telephone number.
  - .2 Provide complete original-issue manufacturer's documentation, brochures and literature, parts list (if available), installation, and maintenance information for all PV system equipment.
  - .3 Provide a warranty list for all items that extend beyond the standard one-year contractor's warranty period.
  - .4 Provide guarantees and warranty documents for all equipment.
- .8 *Test Reports, Certifications:***
  - .1 Pre-operational cleaning reports
  - .2 Identification of disconnecting means: list including location, service items and normal operating position.
  - .3 Electrical inspection approval report
  - .4 Start-up reports of equipment
  - .5 Table of inverter protection settings (if user adjustable)
  - .6 Test and commissioning documentation
  - .7 Guarantee and warranty certificates for all equipment and systems