ALBERTA SOLAR SHOWCASE

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Specifications for Grid-Connected Solar PV Systems

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In partnership with:

FCM
Federation of Canadian Municipalities
Fédération canadienne des municipalités

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Climate Change Central

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DISCLAIMER

Climate Change Central is providing these Specifications as an information resource to organizations that are designing, supplying, installing and commissioning solar photovoltaic (PV) systems.

These Specifications were developed for the Alberta Solar Municipal Showcase project (2005 – 2009) and do not necessarily represent technical, policy or procedural guidelines set out by Climate Change Central, its funders or its project partners.

All of the information contained herein is provided to assist municipalities, businesses and individuals interested in developing their own grid-connected solar PV systems.

The Specifications, which are intended to be used as a complete package, are technically complete to our best understanding at the time of printing and are believed to be technically accurate.

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Section 48 14 00

Solar PV System Introduction

Specifications for Grid-Connected Solar PV Systems

DIVISION 48 **ELECTRICAL POWER GENERATION**

SECTION 48 14 00
SOLAR PV SYSTEM INTRODUCTION

PART 1 - GENERAL

1.1 Project Introduction

.1 This Section summarises the work to design, supply, install and commission a complete grid-dependent solar electricity generation system using photovoltaic (abbreviated as "PV") technology at the:

Address of site: _____

_____

.2 Owner's Project Number: _____

.3 The system will provide electricity into the building or site to which it is electrically connected.

.4 The Sections in Division 48 14 have been written to enable a bidding team to organise itself effectively, efficiently, and competitively, aligning itself with appropriate Design Contractors, Equipment Supply Contractors and trades, and creating a single bid for the Work.

.5 Compliance with Division 48 14 will be straightforward for anyone who is very familiar with designing and installing PV systems.

1.2 Related Instructions

.1 The General Conditions of the Contract, Supplementary Conditions, and General Requirements are a part of this specification and shall be used in conjunction with this Section as a part of the Contract Documents. The Contractor is bound by the provisions of Division 00 and Division 01.

.2 Conform to Section 48 14 01, Solar PV System General Conditions.

.3 Refer to Section 48 14 06, Solar PV System Background Narrative for a primer on PV system design and installation.

1.3 Related Work

.1	Solar PV System General Conditions	Section 48 14 01
.2	Solar PV System Design	Section 48 14 02
.3	Solar PV System Equipment	Section 48 14 03
.4	Solar PV System Installation	Section 48 14 04
.5	Solar PV System Commissioning	Section 48 14 05

1.4 Section Includes

1.5 Reference Drawings

.1 See Section 48 14 02, Part 2.1 for details.

.2

Drawing Series	Sheet No.	Supplied by
Site Plan	S1	Owner
Photograph of south side of building or site showing possible array location and general building or site, trees, attachment slopes, shapes, and any array obstructions or shading	P1	Owner
Photograph of the south view from the possible array location showing trees, obstructions and other buildings	P2	Owner
Photograph of possible mechanical room showing possible inverter and switchgear locations, space and shape	P3	Owner
Photograph of electrical breaker panel	P4	Owner
Electrical Single-Line Drawing	PV1	Owner or modified from drawing from Section 48 14 02
System Interconnection Drawing	PV2	Owner or modified from drawing from Section 48 14 02
Electrical Triple-Line Drawing	PV3	Design Contractor
PV Module Mounting Rack	PV4	Equipment Supply Contractor

1.6 Summary Of PV System Mounting

.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.

.3 The building may be new or existing.

.4 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.

PART 2 - PRODUCTS

The PRODUCTS Parts in Division 48 14 include, but are not limited to:

2.1 Introduction to the Equipment

.1 Section 48 14 03 contains the details for the equipment to be supplied.

.2 The solar PV system consists of a PV array mounted on a building or the ground and supplying a grid-dependent inverter electrically connected to the electrical distribution system of the local Wires Service Provider.

.1 Major equipment includes solar PV modules, PV module mounting rack, grid-dependent inverter, DC disconnect.

.2 Minor equipment includes AC branch circuit breaker, PV module interconnection wiring, DC and AC wiring, conduit, hardware and fittings.

.3 Optional components include PV module by-pass diodes, DC over-current protection, PV combiner boxes, AC disconnect, surge suppression, metering and performance instrumentation.

PART 3 - EXECUTION

The EXECUTION Parts of Division 48 14 include, but are not limited to:

3.1 Introduction to the Design

.1 Section 48 14 02 contains the details for the design to be supplied.

.2 A qualified PV system Design Contractor will furnish the complete system's design and component selection, including the solar PV modules, PV module mounting rack, grid-dependent inverter, DC disconnect, PV module interconnection wiring, all DC and AC wiring, and AC branch circuit breaker.

.3 Optional components include, if required, the AC disconnect, PV module by-pass diodes, DC over-current protection, PV combiner boxes, surge suppression, and client-optional metering.

.4 There will also be building penetrations, building connections, and ground mounting piles as necessitated by the array mounting location.

.5 There may also be regulatory approvals as per the local regulatory requirements and the decision of the Owner.

3.2 Introduction to the Supply of Equipment

.1 Section 48 14 03 contains the details for the services to be supplied.

.2 A qualified PV system Equipment Supply Contractor will furnish the PV-specific components including PV modules, PV module mounting rack, PV module interconnection wiring, grid-dependent inverter, and any PV module diodes, unique PV combiner boxes and DC over-current protection internal to these combiner boxes.

.3 The project will also include supplying full system documentation for the design, array configuration, installation, operation and maintenance, plus Owner training.

3.3 Introduction to the Installation

.1 Section 48 14 04 contains the details for the installation to be supplied.

.2 The Installation Contractor will supply the DC disconnect, AC disconnect, all wiring, AC branch circuit breakers, hardware and fittings.

.3 A qualified Installation Contractor may install the complete system.

.4 A qualified sub-contractor will provide any roof penetrations and connections.

.5 A qualified sub-contractor may be used to assemble the array structure and mount the modules.

.6 The Owner may contract for the installation of roof penetration or any support sleepers separately if the array is mounted on a roof.

3.4 Introduction to the Commissioning

.1 See Section 48 14 05 for details on the commissioning to be supplied.

.2 A system checklist will be followed to determine that the system has been installed completely and is working properly.

3.5 Bid Organisation

.1 It is the Bidder's choice as to how they organise their bids with contractors and sub-contractors.

.2 The system design, equipment supply and system installation functions may be supplied by one or more qualified organisations, whichever the Bidder prefers. See Table 1 for details of typical responsibilities.

Table 1. Summary of Functional Responsibilities

#	Item	Design Contractor	Supply Contractor	Installation Contractor	Roofing Contractor
1.	PV system	Design	Supply	Install	
2.	Regulatory approvals	As per Owner's decision			
3.	PV modules	Select	Supply	Install	
4.	PV module diodes (by-pass or blocking) (if required)	Select	Supply	Install	
5.	PV module mounting rack	Select	Supply	Install	
6.	Wall penetration and connections (if required)			Install	
7.	Roof penetration and connections (if required)				Install
8.	Civil works for ground mounting (if required)			Install	
9.	PV module interconnection wiring	Select	Supply	Install	
10.	PV combiner boxes (if required)	Select	Supply	Install	
11.	DC over-current protection	Select	Supply	Install	
12.	DC disconnect	Select		Supply, install	
13.	DC source circuit wiring	Select		Supply, install	
14.	Grid-dependent inverter	Select	Supply	Install	
15.	Surge suppression (if required)	Select	Supply	Install	
16.	AC disconnect (if required)	Select		Select, supply, install	
17.	AC wiring	Select		Select, supply, install	
18.	Conduit, hardware, fittings			Select, supply, install	

(continued on next page)

Table 1. Summary of Functional Responsibilities (continued)

#	Item	Design Contractor	Supply Contractor	Installation Contractor	Roofing Contractor
19.	Equipment bonding	Design		Supply, install	
20.	Equipment grounding	Design		Supply, install	
21.	System grounding	Design		Supply, install	
22.	Metering (if required)	Select		Supply, install	
23.	AC branch circuit breaker	Select		Supply, install	
24.	System commissioning	Supply	Supply	Supply	
25.	Design documentation	Supply	Supply		
26.	Electrical single-line drawing	Supply	Supply		
27.	Electrical triple-line drawing	Supply	Supply		
28.	System warning signage	Supply	Supply	Install	
29.	Structural design (using qualified personnel)	Supply	Supply		
30.	Equipment documentation	Supply	Supply	Supply	
31.	Installation documentation		Supply	Supply	
32.	Operation and maintenance documentation	Supply	Supply	Supply	
33.	Owner training	Supply	Supply	Supply	

END OF SECTION

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Section 48 14 01

Solar PV System General Conditions

Specifications for Grid-Connected Solar PV Systems

DIVISION 48 **ELECTRICAL POWER GENERATION**

SECTION 48 14 01
SOLAR PV SYSTEM GENERAL CONDITIONS

PART 1 - GENERAL

1.1 Scope

.1 This Section covers general information applicable to all Sections in Division 48 14 as required for a complete grid-connected solar PV. Specific details are found in the relevant Sections.

1.2 Related Instructions

.1 Refer to Section 48 14 06, Solar PV System Background Narrative.

.2 Definitions included in Section 48 14 06 shall apply to all Sections in Division 48 14. Definitions that are unique to PV systems shall take precedence over definitions described elsewhere.

1.3 Section Includes

1.4 Drawings And Graphics

.1 The following drawings and graphics pertain to this specification:

.1 Generic electrical single-line drawing;

.2 Photos supplied by the Owner include:

.1 View of the south building elevation showing the proposed location on the roof for the array and noting any potential shading obstructions;

.2 Proposed location inside the building for placement of the inverter, DC and AC disconnects, electrical breaker panel, electrical meter, any monitoring instrumentation, and any display panels.

.3 Photos supplied by the Owner could also include:

.1 View of the west or east building elevation showing the south-facing roof-line;

.2 View from the approximate array location to the east, south and west from the building, showing trees, foliage, poles, buildings, vent pipes;

.3 Close-up of the roofing material;

.4 Routing of wiring from the inverter location to the array location including any relevant building envelope penetration details showing wire penetration and attachment and roof and wall construction.

1.5 Submittals

.1 Details on any required submittals are described in the relevant Submittal articles in Section 48 14 02 (article 1.8 and 3.1), Section 48 14 03 (article 2.4 and 3.1), Section 48 14 04 (article 1.11 and 3.8).

.2 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.

.3 Any CAD drawings shall be compatible with AutoCAD Release 2002 or higher and shall be provided on magnetic/optical disk and as full-size reproducible drawings.

.4 All drawings shall be neat, clear and well arranged.

.5 When manufacturers' cut sheets apply to a product series rather than a specific product, clearly indicate the data specifically applicable to this project.

.6 Each submitted piece of literature and drawing shall clearly reference the relevant equipment and/or system.

.7 General catalogues are not acceptable as product data sheets.

1.6 Permits

.1 The Owner is responsible for obtaining the development permit, and regulatory and Wires Service Provider approvals for this PV system.

.2 The Installation Contractor is responsible for any electrical and building permits and their inspection.

1.7 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 Canadian Electrical Code
  - .1 Special note is made to highlight:
    - .1 Section 2-024;
    - .2 Section 50 for Solar Photovoltaic Systems; and
    - .3 Section 84 for Interconnection of Electric Power Production Sources;
  - .2 All references to the Canadian Electrical Code in this document shall be to most recent version of the Canadian Electrical Code.
- .3 Local Building By-Laws
- .4 Worker's Compensation Board
- .5 Canadian Standards Association
- .6 Pollution Control Board
- .7 Alberta Building Code
- .8 National Building Code of Canada
- .9 National Fire Protection Association
- .10 Underwriters' Laboratories of Canada

.3 The system design, equipment and installation shall comply with the requirements of:

- .1 The Alberta Distributed Generation Interconnection Guide dated 2002 July 16 or later, or equivalent in other provinces; and
- .2 The micropower interconnection requirements of the Supply Authority.

.4 Installation shall adhere to appropriate sections of CanSIA's *PV and the Canadian Electrical Code* booklet, document #PB020, or equivalent.

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

1.8 Labelling of Safety Standards

.1 Where CSA or ULC standards apply, material and equipment shall be approved by them and shall bear the Canadian-approved CSA or ULC mark or Canadian-approved equivalent.

.2 All electrical equipment and products shall:

.1 Be listed to Canadian electrical standards by CSA or equivalent.

.2 Bear marks as part of their nameplate or covering part of their nameplate certifying it to applicable Canadian standards.

.1 The certification mark shall be as allowed by the most recent version of Alberta's Electrical Safety Information Bulletin STANDATA LEG-ECR-2 (or equivalent in other provinces).

1.9 Ownership Of Proprietary Material

.1 All project-developed drawings and documentation shall become the property of the Owner. These include, but are not limited to:

.1 Project graphic images

.2 Record drawings

.3 All documentation

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 and other Sections herein.

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 DC disconnects

.3 Inverters

.4 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. This includes the terminals of the products.

.1 Wiring, combiner boxes, junction boxes and terminals near the PV modules shall be rated for 90°C.

2.6 Materials

.1 This sub-section contains the minimum recommended materials specifications.

.2 Urethane sealants shall be used for all non-flashed roof penetrations.

.3 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).

.4 Aluminum shall not be placed in direct contact with concrete materials.

.5 Only high quality fasteners are to be used (stainless steel is preferred).

.6 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)

.4 Coated or painted steel (only in low corrosive environments such as deserts).

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), 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, and employ single-crystalline, multi-crystalline or amorphous photovoltaic technology.

.3 The PV modules shall have the following certifications at the time of their delivery on site:

.1 Listed to all applicable CSA standards.

.2 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 the most recent version of Alberta's Electrical Information Safety Bulletin STANDATA LEG-ECR-2 (or equivalent in other provinces).

.3 Special Inspection marks are acceptable certification marks for PV modules.

.4 Certification marks valid for other countries are not valid in Canada.

.4 Each PV module shall have one or more bypass diodes installed in the module junction box if significant shading is expected.

.5 PV modules shall have a minimum 20-year warranty.

.6 The manufactures' brochures of PV modules shall list its module characteristics, including:

.1 Current-voltage (I-V) curves, short-circuit current (I_{SC}), open-circuit voltage (V_{OC}), maximum power current (I_{MP}), maximum power voltage (V_{MP}), temperature coefficients of module power, voltage and current, power tolerance, max. series fuse rating.

.2 Module physical dimensions and weight.

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 Be a single unit.

.2 Have a communication port capable of remote monitoring of inverter operation from a computer or from specialised monitoring equipment.

.3 Be fail-safe.

.4 Meet the requirements for a grid-connected inverter as specified by the Wires Service Providers.

.5 Meet the requirements for the interconnection of an inverter-based micropower generator to the Wires Service Provider to which it is interconnected.

.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.

.1 The certification mark shall be as allowed by the most recent version of Alberta's Electrical Information Safety Bulletin STANDATA LEG-ECR-2 (or equivalent in other provinces).

.2 Notwithstanding the information in STANDATA LEG-ECR-2, Special Inspection marks <u>are not</u> 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 Since this specification is written for grid-dependent PV systems, then inverters that require a battery bank or other energy storage means are not acceptable.

2.9 <u>Wiring</u>

.1 All wiring shall be listed to national and local 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, use 75°C insulation rating.

.8 Conductors #10 and larger shall be stranded.

.9 The use of any exposed conductors or cabling (excluding ground wiring) is not acceptable.

2.10 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 To create a uniform appearance with the array, the mounting rack should easily provide for minor adjustments in PV module positioning to permit uniform spacing between individual modules.

PART 3 - EXECUTION

3.1 Design and Procurement

.1 SEQUENCE OF DESIGN, PRODUCT ACCEPTANCE, APPROVALS, AND SUPPLY

.1 Design the PV system

.2 Send submittals for Owner acceptance

.3 If required by the Owner, obtain development and grid-connection regulatory approvals

.4 Supply the products

3.2 Construction, Commissioning And Testing

.1 SEQUENCE OF CONSTRUCTION, INSPECTIONS, COMMISSIONING AND SYSTEM ACCEPTANCE

.1 Construct the PV system

.2 Get it inspected by the electrical Authority Having Jurisdiction (AHJ)

.3 Visually inspect the system to confirm that it is built to design requirements

.4 Conduction Pre-Operation and Operational Tests

.5 Submit Commissioning Report including results of all tests to Owner

.6 Owner's inspection and acceptance

.7 Complete any outstanding construction and put system into operation

.8 Prepare O&M Manual (Substantial Performance accomplished)

.9 Train and demonstrate system to Owner

.10 Owner's final acceptance (Total Performance accomplished)

.2 SYSTEM TESTS

.1 Furnish all instruments and personnel required for the Tests and keep a written record of the Tests.

.2 See Section 48 14 05 for details of Commissioning Tests.

.3 EQUIPMENT STARTUP

.1 Inspect all equipment prior to starting to ensure full compliance with the equipment manufacturers' specifications and instructions as to the electrical connections, voltages and other applicable considerations.

.2 Installation Contractor shall be responsible to place each item of equipment installed in operating condition, including all PV modules, disconnects, wiring, inverters, *etc*., and to start up each unit and check it for performance.

END OF SECTION

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Section 48 14 02

Solar PV System Design

Specifications for Grid-Connected Solar PV Systems

DIVISION 48 **ELECTRICAL POWER GENERATION**

SECTION 48 14 02
SOLAR PV SYSTEM DESIGN

PART 1 - GENERAL

1.1 General Instructions

.1 This Section covers the design required for the installation, operation and commissioning of a fully-functional grid-connected solar photovoltaic (PV) system.

.2 The PV system is connected to the Wires Owner's electrical distribution system.

.3 Design Contractor shall be responsible for ensuring that design and product selection is complete.

.4 Design Contractor shall work with the Equipment Supply Contractor to ensure that the correct products are provided.

.5 Vendors are encouraged to comment on the design and scope, and offer improvements.

1.2 Scope of Work

.1 Design the system to maximise its benefits to its Owner. See Section 48 14 06 Article 1.19 for a list of possible benefits.

.2 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. Include any client-required metering.

.3 Design and select the wiring, cabling, including PV module interconnections, array source circuit, array output circuit, AC output, equipment bonding, and equipment and system grounding.

.4 Select an appropriate PV module mounting rack.

.5 Design penetration of roof, wall or other attachment structure, or ground piles as appropriate.

.6 Provide Project Record Documents.

.7 Include all the equipment design and selection necessary to provide a functional installed system.

1.3 Related Instructions

.1 The General Conditions of the Contract, Supplementary Conditions, and General Requirements are a part of this specification and shall be used in conjunction with this Section as a part of the Contract Documents. The Contractor is bound by the provisions of Division 0 and Division 1.

.2 Refer to Section 48 14 06, Solar PV System Background Narrative

.3 Conform to Section 48 14 01, Solar PV System General Conditions

1.4 Related Work

1.	Solar PV System Introduction	Section 48 14 00
2.	Solar PV System General Conditions	Section 48 14 01
3.	Solar PV System Equipment	Section 48 14 03
4.	Solar PV System Installation	Section 48 14 04
5.	Solar PV System Commissioning	Section 48 14 05

1.5 Section Includes

1.6 Products Not Designed But Integrated With This Section

.1 Any monitoring instrumentation to track PV system performance

1.7 Quality Assurance – PV System Design Contractor

.1 The PV system Design Contractor shall:

.1 Be a member in good standing with the Canadian Solar Industries Association (CanSIA) during the full duration of the PV system's design, bidding, supply, installation and commissioning process.

.2 Employ personnel with demonstrated reputable experience in multi-module PV design, preferably in grid-connected PV system design.

1.8 Minimum Product Submittals

.1 Manufacturer's description, source, 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).

1.9 Quotation

.1 Furnish total bid price. Include the bid price expiry date and the expected design delivery time.

.2 Show hourly design fee rate and estimated quantity of hours to complete the task.

.3 Show breakout of any sub-contracted work, including design fee rate and estimated hours.

PART 2 - PRODUCTS

2.1 Project Record Documents

.1 Site plan

.1 Show overall location and layout of entire PV system on building or site, including PV array, PV module mounting rack, any PV combiner box, inverter, disconnects, and wire routing with respect to the array.

.2 Show true North, array azimuth angles and distances to site boundaries, or building walls as appropriate for the mounting method and location.

.3 Owner will provide the basic site plan on which to develop this drawing as per Section 48 14 06, paragraph 1.9.9.

.2 Structural drawing suitable for installation.

.1 Show complete assembly and installation instructions for PV module mounting rack. Refer to rack product installation manual and Site Plan where appropriate.

.2 Show structural connection to roof, wall, ground or other attachment structure as appropriate.

.3 Show penetration of roof, wall or attachment structure, or ground piles as appropriate.

.4 Show true North, tilt angles, azimuth angles and locating distances to edges of building attachment structure (roof, wall, canopy, *etc.*) or site boundaries as appropriate for the PV module mounting method and location.

.5 Show any other details so as to complete the drawing for installation.

.3 Electrical single-line drawing, Dwg PV1.

.1 The attached single-line drawing may be used as a guide.

.2 Co-ordinate with timing of the regulatory interconnection process.

.3 Wires Service Providers may require this drawing to be sealed by a professional engineer.

.4 System interconnection drawing, Dwg PV2. (See Section 48 14 04, Table 1)

.1 The attached system interconnection drawing may be used as a guide.

.2 Co-ordinate with timing of system installation.

.5 Electrical triple-line drawing suitable for installation, Dwg PV3.

.1 Show all components and devices, and their relevant electrical capacities and quantities including PV modules, DC disconnect, grid-dependent inverter, AC branch circuit breaker.

.2 Show PV module specifications, specifically P_{MP}, I_{SC}, V_{OC}, I_{MP}, and V_{MP}.

.3 Include all breaker, fuse, and disconnect switch manufacturer, model, voltage rating, current rating

.4 Include all conductor types, number of conductors, gauge sizes and lengths for inter-module connections and connectors, array source circuits, array output circuit, AC circuit, and grounding and bonding of all components.

.5 Include any DC over-current protection, PV combiner boxes, junction boxes, surge suppression devices, AC disconnect, and metering.

.6 Show the Point of Common Coupling at which the interface with the local electrical distribution system occurs.

.7 Include required Canadian Electrical Code signage as indicated in Section 48 14 04 – Solar PV System Installation.

.8 In detail sub-drawings show complete assembly, installation and termination instructions for wiring connections to PV modules, PV combiner boxes, junction boxes, disconnects and inverter.

.9 Show any other details so as to complete the drawing for installation.

.6 Complete bill of materials of electrical components, structural hardware and other equipment required for supplying and installing the system indicating quantity, manufacturer, model/part number for:

.1 PV modules;

.2 PV module mounting rack;

.3 PV module interconnection wiring;

.4 Array source circuit wiring;

.5 Array output circuit wiring;

.6 DC disconnect;

.7 Grid-dependent inverter;

.8 AC branch circuit breakers;

.9 AC wiring;

.10 Grounding and bonding wiring;

.11 PV module by-pass diodes, DC over-current protection, PV combiner boxes, AC disconnect and surge suppression device as may be required; and

.12 Optional metering or other performance measuring equipment.

.7 Provide drawing files as CAD, .DWG, or .DXF versions or as per Owner's specific requirements.

.8 Provide document files as Acrobat .pdf or Word .doc files or as per Owner's specific requirements.

.9 Documents and files shall be suitable for use in preparing the Operation and Maintenance (O & M) manual.

PART 3 - EXECUTION

3.1 Submittals

.1 Within 2 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 final completion.

3.2 PV System

.1 Design and select PV system components according to Generally Accepted PV Design criteria. Use as reference the following documents and others as appropriate:

.1 Section 48 14 06, Solar PV System Background Narrative.

.2 *PV and the Canadian Electrical Code* booklet. Document #PB020. Canadian Solar Industries Association. Ottawa, Ontario.

.3 *Guide to PV System Design and Installation*. Report 500-01-020. Developed by Endecon Engineering for the California Energy Commission, Energy Technology Development Division. Sacramento, California.

.2 Give special attention to the DC ratings for components used in DC circuits.

.3 Size the array to achieve the Owner's requirements for annual electrical energy production.

.4 Ensure area of array attachment structure is capable of handling the array size.

.5 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.

.3 A summary of climate normal conditions for any site can be viewed at the Environment Canada web site at (http://climate.weatheroffice.ec.gc.ca/climate_normals/index_e.html) and selecting the name of the closest municipality to the location of the PV system.

.6 Provide an estimate of the annual and monthly system electricity production.

3.3 DC-AC Inverter

.1 Select a grid-dependent inverter that meets the conditions listed under Acceptable Grid-Dependent Inverters in Section 48 14 01, Solar PV System General Conditions.

.2 The installed location of the inverter shall not violate the manufacturer's warranty provisions, especially as they apply to the environment in which the inverter is operating. Inverters shall be located in a space that restricts the inverter's ambient temperature conditions to be within the extreme high and extreme low range to that which is warranted by the manufacturer.

3.4 PV Module

.1 Select a PV module that meets the conditions listed in under Acceptable PV Modules in Section 48 14 01, Solar PV System General Conditions.

.2 Select the same brand and model for each module in the array.

.3 Use module bypass diodes to counteract severe instances of shading if required.

.4 Select modules that have junction box configurations that best meet system cost and installation conditions. Modules shall have junction boxes connected to leads that meet Canadian Electrical Code Section 50-016, or junction boxes that are openable for the connection of custom leads. Standard heat shrink tubing on non-lockable connectors is permitted to meet the requirements of CE Code Section 50-016(d).

3.5 PV Array

.1 Connect PV modules in series to achieve the required inverter voltage.

.2 Use multiple series strings to achieve the required array power.

.3 Minimise the number of parallel connections.

3.6 Combiner Box

.1 A PV combiner box or other junction box may be needed to connect PV module wires, and contain DC over-current protection or blocking diodes.

3.7 Wiring

.1 Size all wiring to have minimum of electrical losses.

.2 Limit total DC circuit wiring losses to no more than 1% where possible.

.3 Select cable type appropriate to the usage and location.

.4 Select the DC wiring that meets the conditions listed under Wiring in Section 48 14 01, Solar PV System General Conditions.

.5 All DC and AC wiring connected to inverter to conform to requirements given by inverter manufacturer.

3.8 String DC Over-Current Protection

.1 Select appropriately sized series DC over-current protection in each string if:

.1 The PV modules' maximum series fuse specification is less than the sum of the array fault current; and

.2 If the array consists of more than two strings.

.2 Size the DC over-current protection to include any AC back feed from the grid.

3.9 PV Module Mounting Rack

.1 Select a commercially-available PV module mounting system for the appropriate array-to-building attachment structure.

.2 Module mounting rack shall provide for each module to be individually removed for maintenance, repair, or replacement.

.3 Ensure that the bonding of all modules is not broken if a module is removed.

.4 Rack must be appropriate for the array tilt angle, angle of attachment structure, space availability and wind and snow loading.

.5 If the PV array is to be mounted on the ground or on a pole, select an appropriate mounting rack and ground pile system.

3.10 Building Envelope Penetration (if appropriate)

.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.

3.11 DC Disconnect

.1 Design and select a DC disconnect to have a DC current rating appropriate to the PV output circuit. Note whether the DC disconnect needs to be double pole or single pole to meet its DC ratings and design the wiring accordingly.

.2 Position the DC disconnect near to the inverter unless circumstances dictate otherwise.

3.12 Surge Suppression Device

.1 If the inverter does not contain a surge suppression device, select an appropriately sized one, mount it near the inverter, and connect it to the inverter as recommended by the inverter manufacturer.

3.13 AC Disconnect

.1 Contact the Wires Service Provider to determine whether they require a visible-break AC disconnect. A visible-break AC disconnect is only required if required by the Wires Service Provider (Canadian Electrical Code Rule 84-024).

.2 Design and select an appropriate AC disconnect if it is required by the Wires Service Provider or if the breaker panel to which the PV system is connected is out of sight of the inverter or more than about 10 metres away.

3.14 AC Branch Circuit Breaker

.1 Size and select the AC branch circuit breaker according to standard over-current electrical design principles.

.2 Connect the inverter to the breaker panel using a AC branch circuit breaker that does not have markings of "line" and "load".

3.15 Grounding And Bonding

.1 Size and select ground and bonding wire according to Generally Accepted PV Design criteria.

.2 Under no circumstances should multiple connections to ground be specified for current carrying conductors in the system.

.1 Follow inverter manufacturer's specifications for connecting the DC wiring, AC wiring and inverter to grounding and bonding terminals.

3.16 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.

3.17 Regulatory Approvals

.1 If required by the Owner, obtain regulatory approvals to permit the interconnection of the PV system into the local Wires Service Provider’s electrical distribution system.

END OF SECTION

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Section 48 14 03

Solar PV System Equipment

Specifications for Grid-Connected Solar PV Systems

DIVISION 48 **ELECTRICAL POWER GENERATION**

SECTION 48 14 03
SOLAR PV SYSTEM EQUIPMENT

PART 1 - GENERAL

1.1 General Instructions

.1 This Section covers the procurement of equipment and documentation required for the installation of a grid-connected solar photovoltaic (PV) system as per the design work arising from Section 48 14 02.

.2 The PV system is connected to the Wires Owner's electrical distribution system.

.3 Equipment Supply Contractor shall be responsible for ensuring that products provided will work with the system as designed and shall work with the Installation Contractor to ensure products are installed correctly.

.4 Vendors are encouraged to comment on the design and scope, and offer improvements.

1.2 Scope of Work

.1 Furnish the PV modules, PV module mounting rack, PV module interconnection wiring, grid-dependent inverter, and any PV module diodes, unique PV combiner boxes and DC over-current protection internal to these combiner boxes, as per the system design.

.2 Furnish documentation on the products provided, including installation manuals and Operation and Maintenance manual.

.3 Furnish a complete training and instruction program to the Owner.

.4 This work does not include any equipment installation.

1.3 Related Instructions

.1 The General Conditions of the Contract, Supplementary Conditions, and General Requirements are a part of this specification and shall be used in conjunction with this Section as a part of the Contract Documents. The Contractor is bound by the provisions of Division 0 and Division 1.

.2 Conform to Section 48 14 01, Solar PV System General Conditions.

.3 Conform to Section 48 14 02, Solar PV System Design.

.4 Refer to Section 48 14 06, Solar PV System Background Narrative.

1.4 Related Work

1.	Solar PV System Introduction	Section 48 14 00
2.	Solar PV System General Conditions	Section 48 14 01
3.	Solar PV System Design	Section 48 14 02
4.	Solar PV System Installation	Section 48 14 04
5.	Solar PV System Commissioning	Section 48 14 05

1.5 Section Includes

1.6 Products Not Furnished Or Installed But Integrated With This Section

.1 Any monitoring instrumentation to track PV system performance.

.2 PV system regulatory interconnection approvals.

.3 DC disconnect, AC disconnect, string over-current protection external to unique PV combiner boxes, surge suppression, metering, grounding wiring, bonding wiring, array source circuit wiring, array output circuit wiring, AC output wiring, AC branch circuit breakers, standard junction boxes, conduit, cable trays and miscellaneous electrical fittings.

.4 Roof, wall or ground attachment components.

1.7 Quality Assurance – PV System Equipment Supply Contractor

.1 The PV system Equipment Supply Contractor shall:

.1 Be a member in good standing with the Canadian Solar Industries Association (CanSIA) during the full duration of the PV system's bidding, supply, installation and commissioning process.

.2 Employ personnel with demonstrated reputable experience in sales of multi-module PV systems.

.3 Have full parts backup and service availability for this equipment.

1.8 Shipping

.1 Shipping shall use the most cost-effective means that provides security to the integrity of the equipment provided.

.2 Co-ordinate shipping with Owner on-site storage facilities.

1.9 Quotation

.1 Furnish total bid price FOB the Owner. Include the bid quote expiry date and the expected product delivery time.

.2 Furnish PV module pricing in units of $/W.

.3 Furnish inverter pricing in units of $/W.

PART 2 - PRODUCTS

2.1 Product Supply

.1 Furnish products in the Scope of Work as selected and specified by the Project Record Documents.

.2 Any deviation from the Project Record Documents requires the specific approval of the Owner.

.3 Furnish the warranties for the products provided.

.4 MOUNTING RACK

.1 Furnish all hardware required for assembling the PV module mounting rack and structurally attaching them to the appropriate array attachment structure. Refer to structural drawings detailing the building's structural supports for the PV modules.

.2 Array mounting hardware shall be compatible with the site considerations and environment, including wind load, snow load and weight.

.3 Equipment Supply Contractor to take responsibility for attachment to roof as per plans and details.

.4 Wind uplift is responsibility of Equipment Supply Contractor.

.5 Mounting rack design assurance:

.1 Array structural design information and attachment to building shall be sealed by a locally-accredited Professional Engineer;

or

.2 Proprietary attachment methods with demonstrated history of success, warranted by the Equipment Supply Contractor for the site's local conditions and acceptable to the building code, will be accepted in lieu of professional seal.

.6 Special attention shall be paid to minimising the risk from exposed fasteners, sharp edges, and potential damage to the PV modules or support structure.

.7 Corrosion resistance and durability of the mechanical hardware should be emphasised. The use of ferrous metals, contact of dissimilar metals and the use of any wood or plastic components are not permitted.

.5 INVERTER

.1 Furnish written confirmation that the inverter meets the interconnection requirements of the Wires Service Provider.

2.2 Product Acceptance

.1 The Contractor shall only ship the PV modules, inverter and any PV combiner box to the Owner upon the following:

.1 Using a photograph of the nameplate of the products, demonstrate to the Owner that the products meet their applicable Canadian safety codes certification as required in Section 48 14 01, Solar PV System General Conditions.

.2 Failure to meet these requirements may cause products to be rejected at Contractor's expense.

2.3 Product Warranties

.1 Warrant all products provided as follows:

.1 Equipment warranties shall be provided as noted in the General Conditions.

.2 PV system failures during the warranty period shall be adjusted, repaired, or replaced at no additional cost or reduction in service to the Owner.

.2 The Contractor shall respond to the Owner’s request for warranty service within 24 hours during normal business hours.

.3 Provide at no charge, any inverter firmware upgrades that become available during the warranty period.

.4 All work shall have a single warranty date, even when the Owner has received beneficial use due to an early system start-up.

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

.6 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.

2.4 Minimum Product Submittals on Products Provided

.1 A complete bill of materials of electrical components, structural hardware and other equipment required for installing the products indicating quantity, manufacturer, model/part number, and other relevant technical data.

.2 Manufacturer’s description, source, and technical data, such as performance curves, product specification sheets, and installation, maintenance, and operations manuals.

.3 Warranty information.

.4 This may include submittals provided by System Design Contractor.

PART 3 - EXECUTION

3.1 Submittals

.1 Furnish submittals on all products to be provided.

.2 Provide submittals within 2 weeks of contract award.

.3 No work may begin on any segment of this project until submittals have been successfully reviewed for conformity with the design intent.

3.2 Operating And Maintenance (O & M) Manuals [1]

.1 Assemble PV system operating and maintenance manual in consultation with the Owner.

.2 GENERAL

- .1 Submit for approval prior to final completion and include as-built versions of the submittal product data.
- .2 Furnish one (1) complete set to Owner in hard cover binder.
- .3 Referencing key specific page numbers in equipment manuals is acceptable where available.

.3 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).

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[1] Refer to notes on Documentation and System Commissioning in Section 48 14 06, Solar PV System Background Narrative.

.3 Provide an overview of major system components (array, inverter, disconnects, over-current protection) and their connections. Section 48 14 06 may contain useful text.

.5 Operators Manual: [2]

.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: [2]

.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.

.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.

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[2] Referencing key specific page numbers in equipment manuals is acceptable where available.

.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

3.3 Training

.1 Provide a 1-hour on-site training session for personnel designated by the Owner.

.2 Training session to include the following:

.1 Operate the PV system, know the location of control components, know how to turn on and off the system

.2 Demonstrate all control functions, operating modes and emergency procedures

.3 Understand all system equipment, their location and connection to other equipment

.4 Understand system operation, including factors affecting its optimal operation

.5 Adjust and change inverter settings (if available)

.6 Access graphics, data reports, and logs (if available)

.7 Recognize malfunctions of the system by observation of visual information

.8 Perform checkout and maintenance procedures for maintaining, troubleshooting, diagnosing, and repairing hardware

.9 Understand system drawings and Operation and Maintenance manual.

.3 Perform training session in the daytime using the completed Operation and Maintenance Manual.

END OF SECTION

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Section 48 14 04

Solar PV System Installation

Specifications for Grid-Connected Solar PV Systems

DIVISION 48 **ELECTRICAL POWER GENERATION**

SECTION 48 14 04
SOLAR PV SYSTEM INSTALLATION

PART 1 - GENERAL

1.1 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 and supply work arising from this Division.

.2 The PV system is connected to the Wires Owner's electrical distribution system.

.3 Installation Contractor shall be responsible for ensuring that the products provided will work together. Installation Contractor shall work with the Equipment Supply Contractor to ensure products are installed correctly.

.4 Vendors are encouraged to comment on the installation and scope, and offer improvements.

1.2 Scope of Work

.1 Work shall include all the installation, equipment, hardware and commissioning necessary to complete the system installation.

.2 Perform all General Contractor duties for the Work including laying out the array location, co-ordinating the installation and site work (as appropriate) and the work of any Sub-Contractors or specialties the Contractor assigns for the work.

.3 Solicit from Owner all specifications and details of Owner-furnished materials.

.4 Provide all labour, miscellaneous material, electrical fittings, raceways, and hardware, and tools as required to complete the installation of the PV system, including any building envelope penetration, connection to the building's electrical distribution system, and attachment to the building structure or ground.

.5 Furnish the DC disconnect (if required), AC disconnect (if required), grounding wiring, bonding wiring, array source circuit wiring, array output circuit wiring, AC output wiring, AC branch circuit breakers.

.6 Size of any raceway shall be the responsibility of the Installation Contractor.

.7 Installation Contractor is responsible for making the system workable. As such if required, furnish any other hardware required such as PV string over-current protection that is external to unique PV combiner boxes, surge suppression, metering, junction boxes, conduit, cable trays and electrical fittings.

1.3 Related Instructions

.1 The General Conditions of the Contract, Supplementary Conditions, and General Requirements are a part of this specification and shall be used in conjunction with this Section as a part of the Contract Documents. The Contractor is bound by the provisions of Division 0 and Division 1.

.2 Conform to Section 48 14 01, Solar PV System General Conditions

.3 Refer to Section 48 14 06, Solar PV System Background Narrative

1.4 Related Work

1.	Solar PV System Introduction	Section 48 14 00
2.	Solar PV System General Conditions	Section 48 14 01
3.	Solar PV System Design	Section 48 14 02
4.	Solar PV System Equipment	Section 48 14 03
5.	Solar PV System Commissioning	Section 48 14 05

1.5 Section Includes

1.6 Products Not Furnished Or Installed But Integrated With This Section

.1 Local area networks

.2 Regulatory approvals for the interconnection of this PV system to the electrical grid

.3 Installation manuals and Operation and Maintenance manual

.4 Training and instruction program for the Owner

1.7 Products Installed But Not Furnished With This Section

.1 PV modules, PV module mounting rack, PV module interconnection wiring, grid-dependent inverter, PV module diodes, unique PV combiner boxes and DC over-current protection internal to these combiner boxes as provided by Equipment Supply Contractor

.2 Any monitoring instrumentation to track PV system performance

1.8 Quality Assurance - Installation

.1 This system shall be installed by a team with demonstrated experience in electrical and PV system supply and installation.

.2 Maintain a contractual relationship with a Master electrician, who will carry the responsibility for the installation.

.3 Contractor experience:

.1 LESS EXPERIENCE – If Contractor has installed fewer than 6 multi-module PV systems, the Contractor shall work as a team with the Equipment Supply Contractor; or

.2 MORE EXPERIENCE – If Contractor has installed 6 or more multi-module PV systems, the Contractor shall:

.1 Have an established working relationship with a qualified PV system Equipment Supply Contractor as per Section 48 14 03 Clause 1.7;

.2 Present for review a list of 6 installed systems upon request; or

.3 TRAINED – The Contractor shall hold an installation Certificate offered by an independent and qualified training institution, and shall present for review the certification of completed training (minimum 30 hours), upon request; or

.4 Present approved equivalent qualifications prior to tender closing (approval shall be by the Owner).

1.9 Quality Assurance - Building Envelope

.1 Any building envelope penetrations to be installed by personnel acceptable to the Owner.

1.10 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 protected. PV module to module wiring is exempt from protection.

.4 All communication wiring shall meet Canadian Electrical Code Class 2 standards.

.1 Do not install Class 2 wiring in raceway containing Class 1 wiring. Boxes and panel boards containing AC line-voltage or DC array wiring and equipment may not be used for communication wiring except for the purpose of interfacing the two (*e.g.*, relays and transformers).

.2 Where Class 2 wiring is run exposed, wiring is to be run parallel along a surface or perpendicular to it and *neatly* tied at 1 m intervals.

.5 Wiring shall be continuous for each wiring run. Splices shall only be allowed in splice boxes.

.6 All wiring within enclosures shall be neatly bundled and anchored to permit easy access to devices and terminals.

.7 All exposed conduits shall be rigid galvanized steel.

.8 In interior areas exposed to moisture, including chiller and boiler rooms, liquid-tight, flexible metal raceways shall be used. Flexible metal raceways and liquid-tight, flexible metal raceways shall not exceed one metre in length and shall be supported at each end. Flexible metal raceway less than ½ in. electrical trade size shall not be used.

.9 Raceway must be rigidly installed, adequately supported, properly reamed at both ends, and left clean and free of obstructions. Raceway sections shall be joined with couplings. Terminations must be made with fittings at boxes, and ends not terminating in boxes shall have bushings installed. Seal top end of all vertical raceways.

.10 Outdoor raceways that are visible from the ground or raceways installed in finished areas shall be painted as required by the Owner.

.11 Conceal all raceways, except within mechanical, electrical, or service rooms.

.12 Install raceway to maintain a minimum clearance of 150 mm from high-temperature equipment (*e.g.* steam pipes or flues).

.13 Secure raceways with raceway clamps fastened to the structure and spaced according to code requirements. Raceways and pull boxes may not be hung on flexible duct strap or tie rods. Raceways may not be run on or attached to ductwork.

.14 Adhere to standard practice and requirements where raceway crosses building expansion joints.

.15 All wire-to-equipment connections shall be made at a terminal block or terminal strip when supplied with the equipment.

1.11 Minimum Product Submittals

.1 A complete bill of materials of electrical components, structural hardware and other equipment required for installing all products for the system indicating quantity, manufacturer, model/part number, and other relevant technical data.

.2 Manufacturer's description, source, and technical data, such as performance curves, product specification sheets, and installation, assembly, maintenance, and operations manuals.

.3 Warranty information on products provided.

.4 This may include submittals provided by Equipment Supply Contractor.

1.12 Warranty

.1 The warranties supplied in this Section are to be included in the warranty requirements of Division 1.

.2 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 Division will be free from defects of material and workmanship for a period of _____ 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.

.3 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.

.4 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.

.5 Additional equipment warranties shall be provided as noted in this Division.

.6 PV system failures during the warranty period shall be adjusted, repaired, or replaced at no additional cost or reduction in service to the Owner.

.7 The Contractor shall respond to the Owner's request for warranty service within 24 hours during normal business hours.

.8 All work shall have a single warranty date, even when the Owner has received beneficial use due to an early system start-up.

.9 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.

.10 Provide at no charge, any inverter firmware upgrades that become available during the warranty period.

.11 In default, Owner may have such work done and charge costs to Contractor.

.12 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.

.13 This warranty is invalid if the system is modified in any way without the consent of the Contractor.

1.13 Laws, Notices, Permits And Fees

.1 With the exception of development permits and regulatory approvals for the interconnection of this PV system, give all necessary notices, obtain all necessary permits and pay all fees in order that the work in this Section may be carried out.

1.14 Quotation

.1 Furnish total bid price FOB the Owner. Include the bid quote expiry date and an expected installation schedule.

.2 If the Owner has a cost allowance for any portion of the installation work, such as shown in Division 1, such as the installation of roof penetration, any support sleepers or piles, include a cost allowance equal to this quote or estimate as a line item in the Bid Price.

PART 2 - PRODUCTS

.1 Furnish products as selected and specified in the Scope of Work according to the Project Record Documents.

.2 Deviation from the Project Record Documents listing or arrangement specified on the design drawings requires the specific approval of the Owner.

.3 Furnish the warranties for the products provided.

PART 3 - EXECUTION

.1 The Work includes, but is not limited to the following:

3.2 Regulatory Interconnection Approvals

.1 The installation of the PV system cannot be started before obtaining a written approval from the appropriate Wires Service Provider or electric industry regulator. The Contractor that obtains this approval will be determined by the Owner.

3.3 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.

3.4 Safety Protection

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

3.5 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.

3.6 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.

3.7 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.

3.8 Submittals

.1 SCHEDULES

.1 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.

.2 Provide regular written status reports indicating work completed, revisions to expected delivery dates and updated project schedule as required by the Owner.

.2 PRODUCT DATA

.1 Within _____ weeks of contract award, furnish submittals on following items:

.1 Building attachment including roof or wall penetration, or ground foundation work.

.2 PV support rack submittals including schedule of rack members, fittings, and rack layout.

.3 Schedule of PV modules, inverter, all disconnects, array source circuit wiring, array output circuit wiring, AC output wiring.

.2 No work may begin on any segment of this project until submittals have been successfully reviewed for conformity with the design intent.

.3 Accept liability for removal and replacement at no extra charge to the Owner if material or equipment is installed prior to receipt by the Contractor of pertinent shop drawings from the Owner marked "No Exceptions Taken" or "Comments as Noted".

.3 PROJECT RECORD DOCUMENTS

.1 Upon completion of installation, submit record (as-built) documents as follows.

.2 The documents shall be submitted for approval prior to final completion.

.3 Project Record Drawings shall be as-built versions of the submittal shop drawings. Provide drawing files as CAD, .DWG, or .DXF versions or as per Owner's specific requirements.

.4 Testing and Commissioning Reports and Checklists, including completed versions of all reports and checklists.

.5 Operation and Maintenance (O & M) Manual, including as-built versions of the submittal product data.

.4 PROJECT RECORD DRAWINGS (AS-BUILT)

.1 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.

.2 Clearly indicate on the drawings the actual condition of the installed PV system at the time of final acceptance.

.3 Certify the accuracy of each drawing by endorsing and signing each marked drawing.

.4 When work is complete, furnish one (1) complete "Record" set of marked drawings.

.5 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.

3.9 Examination

.1 Thoroughly examine the project plans for PV equipment locations, and inspect the site to verify that equipment may be installed as shown. Any discrepancies, conflicts, or omissions shall be reported to the Owner for resolution before rough-in work is started.

.2 Examine the drawings and specifications for other parts of the work. If any discrepancies occur between the plans and the Contractor's work and the plans and the work of others — report these discrepancies to the Owner and obtain written instructions for any changes necessary to accommodate the Contractor's work with the work of others. Any changes in the work covered by this specification made necessary by the failure or neglect of the Contractor to report such discrepancies shall be made by, and at the expense of, this Contractor.

3.10 Protection

.1 Protect all work and material from damage by work or employees and be liable for all damage thus caused.

.2 Be responsible for work and equipment until finally inspection, testing, and acceptance.

.3 Protect any material that is not immediately installed.

.4 Protect Work from damage from other trades.

3.11 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.

3.12 Delivery

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

3.13 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 responsibility 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.

3.14 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 contractor's association.

.3 Seal roof penetrations to building code requirements.

.5 Properly size all wiring penetrations of the building envelope.

3.15 Installation – Array Ground Mounting

.1 If the array is to be ground mounted, construct piles as per Project Record Documents, as per standard practice for piles, and as per mounting rack manufacturer specifications.

3.16 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 with nameplate values.

.2 Estimate and record ambient air temperature and solar radiation conditions.

.3 Complete the testing under sunny conditions.

.4 In the event the measurements are out of the expected ranges, deem the module defective and notify the Equipment Supply Contractor.

.5 Defective modules are not to be installed.

.6 Submit a copy of all testing records to the Owner.

3.17 Installation – PV Array

.1 Co-ordinate the PV array installation with building envelope penetration or groundwork.

.2 Ensure 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 Modules must fit snug against the rack. Do not twist the module to force a fit since the glazing may shatter.

.6 Adjust PV module position to achieve uniform spacing between modules.

.7 Ensure corrosion resistance and durability of all mechanical hardware.

.1 The use of ferrous metals and wood or plastic components is not permitted.

.2 Be aware of the effects of dissimilar metal contact and choose materials and methods to minimise or eliminate these effects.

.8 Use live wiring methods when connecting the PV modules, since the modules are electrically "alive" as soon as they are exposed to light.

.9 Provide lock-washers to prevent “backing out” of nuts at all bolted connections. Use stainless steel fasteners only.

3.18 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.

3.19 Installation – Wiring

.1 Install all wiring connections and terminations at PV modules and inverters in accordance with manufacturers’ recommendations.

.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 Permanently label the exterior or interior of all junction boxes containing PV DC circuits with the words “Warning: Live during Daylight Hours” as per Table 2.

3.20 Installation – System

.1 For safety, it is recommended that the installation crew always have a minimum of two people working together.

.2 All drawings, component manuals (especially inverter manuals), are to be read and understood prior to installation.

.3 Install all equipment in readily accessible locations as defined by the Canadian Electrical Code.

.4 Comply with component manufacturer’s instructions to provide a fully integrated and operational system. Ensure that all required and recommended clearances are maintained.

.5 Prior to system installation ensure that all disconnects are in the OPEN position and all fuses (if any) removed from DC circuits, and all component switches are in the OFF position and all AC fuses removed.

.6 Connect PV system to the building’s electrical distribution system.

.7 Verify integrity of all wiring to ensure continuity and absence from electrical short circuits.

.8 Properly ground the system equipment to reduce the threat of shock hazards and induced surges.

.9 Ensure the installation meets local Wires Service Provider's interconnection requirements.

.10 Have final inspections completed by the Authority Having Jurisdiction (AHJ) and the Wires Service Provider (if required).

.11 The PV System shall not be left operational without the permission from the local Wires Service Provider.

.12 The Contractor shall notify the Owner in writing when the entire PV system is installed, and the preliminary field-testing is successfully completed.

3.21 Installation – Monitoring Equipment

.1 If monitoring equipment is to be installed:

.1 Confirm before installation that the Owner has installed a suitable internet communication cable between their internet router and the monitoring equipment, 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.

3.22 Identification Of Components

.1 Furnish and install permanent as-built drawings as per Table 1.

.2 Clearly identify all control devices (*i.e.*, circuit breakers, switches, AC and DC disconnects) as to their function and the equipment controlled.

.3 Clearly identify inverters and the panel board they serve.

.4 Identification text shall be minimum 19 mm high white on surrounding black.

.5 Furnish and install warning signs as per Table 2. Contact the Wires Service Provider's distributed generation staff to determine whether they will need any warning signs in addition to Table 2, such as a sign on the building's service entrance weatherhead. All warning signs to be white letters on red background.

.6 All equipment labels and warning signs shall be permanent self-adhesive engraved phenolic (lamacoid-type) legend plates with standard engraver’s letter style, using a standard size appropriate for the application. Minimum thickness of labels shall be 1.6 mm.

3.23 Cleaning

.1 Daily clean up all debris resulting from activities. Remove all cartons, containers, and crates under Contractor's control as soon as their contents have been removed, and place in a designated location for recycling.

.2 At the completion of work in any area, clean all work, equipment keeping it free from dust, dirt, filings, grease, tape residue and debris.

.3 At the completion of work, check all equipment furnished under this Section for paint damage, and repair any factory-finished paint that has been damaged to match the adjacent areas. Replace any cabinet or enclosure that has been deformed with new material and repainted to match the adjacent areas.

3.24 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 Submit all field test results to the Owner for approval.

.4 The Wires Service Provider 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.

.5 Correct all installation defects identified by the field testing.

3.25 System Commissioning

.1 If required by the Owner, commission the PV system by following the commissioning procedures in this Division.

3.26 System Acceptance

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

Table 1. Permanent Drawings [1]

#	Permanent Drawing	Location	Reason	Holes?	Location	Typical Width [2]	Typical Height [2]
1.	System interconnection drawing, PV2	On inverter AC disconnect	Requirement of CE Code 84-030(2)	No	Indoor	140 mm	210 mm

[1] Suggestion: Fabricate the drawing from laminated paper made from a standard letter paper photocopied at ~70%, or less.

[2] Size the dimensions to fit the sign's location. Typical dimensions shown may be useful.

Table 2. Warning Sign Details

#	Warning Sign	Location	Reason	Mounting Holes	Sign Location	Typical Width [2]	Typical Height [2]
1.	Solar Array Rating Voc XXX VDC [3] Isc X.X ADC [4] Vmp XXX VDC [5] Imp X.X ADC [6]	On DC disconnect next to inverter	Requirement of CE Code 50-004	Not required	Indoor	80 mm	40 mm
2.	Solar Electric System Two electric source parallel system	At inverter's AC disconnect	Requirement of CE Code 84-030(1)	Not required	Indoor	60 mm	40 mm
3.	Solar Electric System Two electric source parallel system	At the building's meter	Requirement of CE Code 84-030(1)	Yes	Outdoor	100 mm	75 mm
4.	Inside parts can be energized when switch is open	On inverter's AC disconnect	Requirement of CE Code 84-024(1)(i)	Not required	Indoor	80 mm	40 mm
5.	Solar Electric System	Next to PV system's breaker at breaker panel	Visibility and clarity	Not required	Indoor	50 mm	25 mm
6.	Warning: Live during Daylight Hours Max XXX VDC [3]	On inside or outside of any junction box with solar array DC circuits	Highly recommended for safety. This is not yet in the CE Code.	Not required	Indoor	50 mm	25 mm

END OF SECTION

[3] XXX is the open circuit voltage of the PV array – typically 200 to 600 volts DC.
[4] X.X is the short circuit current of the PV array – typically 4 to 30 amperes DC.
[5] XXX is the voltage of the PV array at its rated operating point – typically 200 to 400 VDC.
[6] X.X is the amperage of the PV array at its rated operating point –typically 4 to 15 ADC.

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Section 48 14 05

Solar PV System Commissioning

Specifications for Grid-Connected Solar PV Systems

DIVISION 48 **ELECTRICAL POWER GENERATION**

SECTION 48 14 05
SOLAR PV SYSTEM COMMISSIONING

PART 1 - GENERAL

1.1 General Information

.1 This Section covers the commissioning of a grid-dependent solar photovoltaic (PV) system as per the design, supply and installation work arising from this Division.

.2 The goal of the commissioning is to:

.1 Provide effective commissioning documentation to the Owner;

.2 Assist in the verification and inspection of the PV system after installation and for subsequent re-inspection, maintenance or modifications; and

.3 Verify that the system has been installed according to the design and the manufacturer's procedures.

.3 This includes the commissioning tests, inspection criteria and documentation expected to verify the safe installation and correct operation of the system.

.4 It is recommended that the Design Contractor provide the commissioning work.

1.2 Scope of Work

.1 Perform the commissioning work at the completion of the system installation.

.2 Provide all labour, miscellaneous material, and tools as required to complete the commissioning of the PV system.

1.3 Related Instructions

.1 The General Conditions of the Contract, Supplementary Conditions, and General Requirements are a part of this specification and shall be used in conjunction with this Section as a part of the Contract Documents. The Contractor is bound by the provisions of Division 0 and Division 1.

.2 Conform to Section 48 14 01, Solar PV System General Conditions

.3 Refer to Section 48 14 06, Solar PV System Background Narrative

1.4 Related Work

1.	Solar PV System Introduction	Section 48 14 00
2.	Solar PV System General Conditions	Section 48 14 01
3.	Solar PV System Design	Section 48 14 02
4.	Solar PV System Equipment	Section 48 14 03
5.	Solar PV System Installation	Section 48 14 04

THIS SECTION IS TO BE COMPLETED AND WILL BE POSTED BY 2009 MAY 31

END OF SECTION

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Section 48 14 06

Solar PV System Background Narrative

Specifications for Grid-Connected Solar PV Systems

DIVISION 48 **ELECTRICAL POWER GENERATION**

SECTION 48 14 06
SOLAR PV SYSTEM BACKGROUND NARRATIVE

PART 1 - GENERAL

1.1 General Information

.1 This Section is not mandatory.

.2 This Section is provided for anyone who may not be familiar with solar photovoltaic (abbreviated as "PV") systems. It is expected that Contractors who are familiar with PV systems will quickly read many of the requirements of these specifications and know that they already are in compliance with them.

.3 It provides background reference information for the development of projects using grid-dependent solar PV technologies. Its prime value is in helping readers understand PV technology and why the specifications are written as they are.

.4 It includes a description of the components and operation of PV systems and recommendations and cautions regarding various parts of the system's development.

.5 The specific requirements of this Contract are contained in the Sections of technical specifications listed in Article 1.2 "Related Instructions" below.

1.2 Related Instructions

.1	Solar PV System Introduction	Section 48 14 00
.2	Solar PV System General Conditions	Section 48 14 01
.3	Solar PV System Design	Section 48 14 02
.4	Solar PV System Equipment	Section 48 14 03
.5	Solar PV System Installation	Section 48 14 04
.6	Solar PV System Commissioning	Section 48 14 05

1.3 Section Includes

1.4 Grid-Dependent Solar PV System

.1 Solar radiation at the earth's surface consists of photons of light. A solar PV system converts the energy contained in these photons into electricity. This electricity can be used to energise any electricity-consuming device.

.2 A grid-dependent solar PV system consists of four main components, as shown in Figure 1:

- an array of solar PV modules;
- a DC disconnect, where required;
- a grid-dependent inverter and,
- an AC disconnect, where required.

.3 Other system components include

- PV module mounting rack(s),
- ground-mounted or building-mounted attachments,
- electrical energy wiring and cabling,
- a branch circuit breaker,
- documentation,

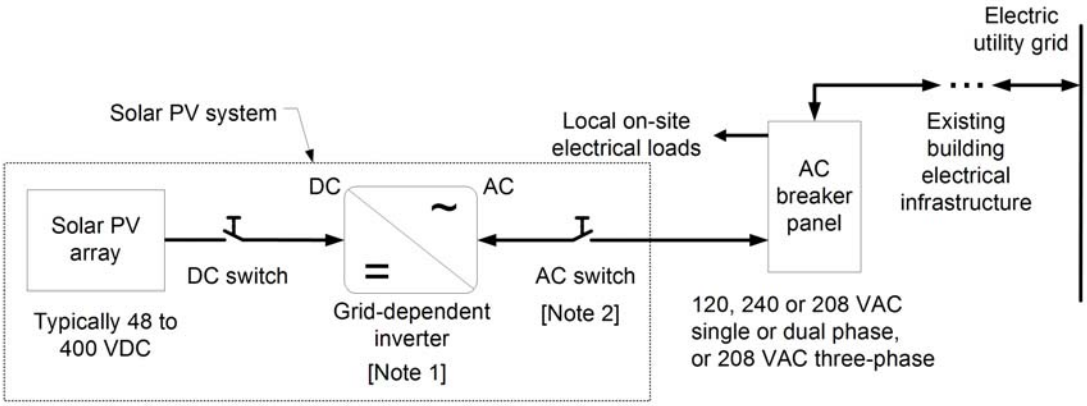
and sometimes

- a PV combiner box,
- blocking diodes,
- bypass diodes,
- array tracking,
- instrumentation and wiring, and
- electrical metering.

.4 The solar PV system connects to on-site loads through a back-fed standard AC branch circuit breaker without load and line markings.

.5 The system connects to the distribution system of the local electric wires company (utility) through the on-site electrical distribution system.

.6 System labour includes design, regulatory approvals, specification, procurement, installation, commissioning, documentation and training.



NOTES:
1. Grid-dependent inverters are certified to meet the safety protection specifications required by the electric utility and the Canadian Standards Association (CSA).
2. The option, location and specification of the AC switch are given by the requirements of the electric utility and the Canadian Electrical Code.

Figure 1. Configuration of a Grid-Dependent Solar PV System

1.5 System Operation

.1 The objective of a load-offset solar PV system is to generate electricity for any of the on-site AC electrical loads, with any moment by moment excess fed into the grid.

.2 The PV array generates DC electricity, which is converted by the inverter to AC electricity, which is then reverse-fed into a breaker on a breaker panelboard anywhere in the building or on site.

.3 A PV system firstly energises electricity-consuming devices that are electrically closest to its own breaker. As its generating rate increases with greater levels of solar radiation, it energises devices that are electrically further away.

.4 Any electricity that is surplus to on-site needs at any moment is fed back into the local utility distribution system (colloquially called the grid) if the instantaneous on-site electricity consumption is less than the PV system's AC generation at that moment.

.1 There is no technology currently on the market that practically prevents this electricity from being fed to the grid from a grid-dependent PV system during normal grid operation.

.5 A grid-dependent PV system automatically turns off every night, and turns on and begins generating electricity at the start of every day.

1.6 Energy Production

.1 The amount of electricity that is produced depends primarily on the rate at which photons are incident on the system's solar PV modules, and secondarily on the inverse of the temperature of the modules (lower temperatures increase the module efficiency).

.2 Factors that reduce the production of electricity include:

- array shading from objects and structures such as clouds, snow, dirt, foliage, buildings, and poles;
- higher PV module temperatures; and
- module age (production typically reduced by ½% per year).

.3 Factors that increase the production of electricity include:

- clearer skies;
- reflected solar light from nearby surroundings such as fields of snow;
- higher efficiency PV modules;
- optimal array tilt and azimuth angles; and
- cooler ambient air temperatures.

.4 Losses in a PV system's production are reduced by:

- using the same PV modules;
- minimising the number of wiring connections;
- increasing the wiring size; and
- using a high-efficiency inverter.

.5 Avoid shading on an array. Even small amounts of shading effectively diminish the electricity production due to the manner in which PV cells are electrically connected in modules.

.6 A PV system's production is stopped by tarps, by night, and by amounts of snow more than a few centimetres in accumulation.

.7 Solar tracking systems can increase electricity production up to 40% depending on the local cloud conditions and the type of tracking system.

.8 Typically in Alberta, a PV system generates between 900 kWh to 1300 kWh of electrical energy per year per kW of rated generating capacity, depending on its location, latitude, tilt angle and orientation angle. This value is known as the system’s “final yield” and has units of “hours per year”. This means that the amount of electrical energy generated by the PV system over a year is the same

as if it operated for 1000 hours (for example) at its rated capacity and then was turned off for the rest of the year. This is synonymous with an annual "capacity factor" of 10% to 15%.

1.7 Components

.1 SOLAR PV MODULES

.1 A solar PV module consists of a number of PV cells in a combination of series and parallel electrical connections, typically 36 or 72 in series.

.2 The generating capacity of a module is rated at Standard Test Conditions.

.3 Typical module efficiencies are 11% to 17%. This decreases with increasing temperature and electrically mis-matched modules.

.4 A PV module's nameplate indicates its most important electrical design and operating characteristics. These characteristics include short-circuit current (I_{SC}), open-circuit voltage (V_{OC}), maximum power current (I_{MP}), maximum power voltage (V_{MP}), and rated power output (P_{MP}).

.5 Typically a module includes one or more bypass diodes installed in its junction box.

.6 PV modules can be supplied with sealed junction boxes connected to leads and plug connectors (such as MC Connectors) for inter-module connections, or openable junction boxes to which field-installed leads are attached.

.1 There are advantages and disadvantages of both configurations. The choice of which one to select depends on the array installation details.

.2 Plug connectors can reduce array installation time significantly. Where only non-lockable connectors are available, standard heat shrink tubing is permitted to meet the requirements of CE Code Section 50-016(d).

.7 PV modules typically have warranties of between 20 and 30 years.

.8 PV modules need to have a label certifying that they meet ULC/ORD C1703-01 – "Flat Plate Photovoltaic Modules and Panel", “IEC 61730 – Photovoltaic Module Safety Qualification (Part 1 and 2)", or updated equivalent, as appropriate to the module’s technology.

.9 Typically PV modules are "flat plate" as compared to "concentrating". Concentrating modules work most effectively when a large proportion of the solar radiation is derived directly from the sun's disk (called beam radiation) as compared to indirectly as scattered by the sky and clouds (called diffuse radiation). Concentrating modules need to track the sun and are not widely supplied on a commercial basis.

.10 PV modules produce power directly from sunlight. They are electrically ‘live’ as soon as they are removed from their shipping box and exposed to light.

.2 SOLAR PV ARRAY

.1 A solar array consists of PV modules in which (typically) each module is the same as all the others in the array. Module "mis-match" losses are reduced when all the modules in an array are the same brand and model number.

.2 The modules in an array are configured in a combination of series and parallel electrical connections to meet the input requirements of the inverter.

.1 Modules connected in series achieve the DC input voltage that the inverter requires to operate.

.2 Multiple strings of modules connected in parallel achieve the required array power.

.3 The number of parallel connections should be minimised.

.4 Low voltage arrays such as 12 volts DC and 24 volts DC have more parallel connections. Higher voltage arrays from 40 volts DC to 400 volts DC have more series connections.

.5 Often small high voltage arrays consist of only one string.

.3 Standard electrical system safety practices need to be employed in the operation, maintenance, or testing of a PV system.

.1 The key consideration of a PV system related to safety is that, when illuminated, a PV module or array is capable of providing its full open circuit voltage and being a shock hazard even under conditions of low solar irradiance.

.1 A PV array cannot be “turned off” while illuminated. It can only be turned off by preventing photons from reaching the PV cells. Thus, there are only two methods of turning off a PV array: wait until dark or cover with an opaque material.

.2 Covering a PV array incompletely, with a material that is translucent, or with a material that has tears or gaps may not completely disable the array.

.3 Take care when wiring PV modules to avoid electrical shock. Live wiring methods should be employed.

.4 A PV array gets hot and can easily reach temperatures of 75°C.

.3 SOLAR PV MODULE MOUNTING

.1 An array is mounted onto a rack assembly, usually comprising aluminum structural members, that is then mounted onto attachment points protruding from a building's roof, wall, awning or other array attachment structure. A mounting rack can also be placed on a foundation in the ground such as piles, or on a pole mounted on a foundation in the ground.

.2 Array mounting is usually at a fixed tilt and azimuth angle.

.3 PV systems are often high profile and publicly visible installations. As a result, the aesthetics of the overall installation can be extremely important to the Owner. To create a uniform appearance with the array, the mounting rack should easily provide for minor adjustments in module positioning to permit uniform spacing between individual modules. It is found that if modules are too close, then minor differences in spacing can look odd, whereas if modules are at least 15 mm apart then minor spacing differences are not noticeable.

.4 Passive air circulation facilitated by the array mounting design can be important in increasing the efficiency of the array.

.5 It is very helpful for array maintenance and troubleshooting to provide access to the back of the array, such as for servicing module junction boxes and removal and replacement of modules. This is not always possible.

.6 An array can be integrated into a number of building cladding products, such as shingles, roof tiles, wall panels, and windows. This is termed a building integrated PV (BIPV) system.

.4 TRACKING

.1 Solar tracking can be employed to increase the amount of electricity production. Tracking equipment can be configured as:

.1 A horizontal or tilted north-south axis that rotates to track the sun across the sky daily;

.2 An east-west axis that rotates to track the sun across the sky daily;

.1 Seasonal tracking is usually a manual adjustment of this type of tracking configuration.

.3 Azimuth tracking where an array on a fixed tilt tracks the sun across the sky daily around a vertical axis; and

.4 2-axis tracking, which tracks the sun daily and seasonally, using a gimballed mechanism like a satellite dish.

.2 Typically tracking systems are not used because

- their cost can be similar to a larger PV array at a fixed tilt that generates the same amount of electricity as the tracking array, and
- they may need maintenance.

.5 WIRING AND CABLING

.1 Energy is transferred from the PV modules to the inverter and the building through its wiring and cabling.

.2 The Canadian Electrical Code requires that the maximum voltage drop is 3% in any circuit and 5% overall. For PV systems, however, since the electricity is very expensive, the common practice is to limit PV source circuit and PV output circuit losses to no more than 1%.

.3 Since the PV array gets hot, all wiring, terminals and boxes near the array need to be certified for 90°C conditions.

.6 SUB-ARRAY COMBINER BOX

.1 A unique PV combiner box or a standard junction box may be used to join DC wiring.

.2 It is very helpful in the installation and trouble shooting of PV module connections to make the layout of the array consistent with the ordering and labelling of the array source circuits in the combiner box.

.7 TERMINATIONS

.1 Wiring joints need to be minimised to reduce the risk of high resistance in the joints and thus the potential for the development of DC arcs.

.2 All terminations need to use CSA listed box terminal or compression type connections. Twist-on wire splices (marrette connectors), crimped, soldered or taped connections should not be permitted for field wiring. This

is to ensure highly reliable, long-life connections and reduce the risk of high resistance terminations.

.3 Proper torque specifications should be provided for all field connections.

.8 DIODES

.1 PV module bypass diodes are mounted inside each module to counteract the destructive effects of severe instances of shading. They are often only employed if severe shading is expected.

.2 String blocking diodes prevent reverse current from one string of modules affecting other strings if a fault occurs. These are not needed and have gone out of practice.

.9 DC DISCONNECT

.1 A DC disconnect switch is positioned between the array and inverter to disconnect the inverter from the array. Note that it does not turn off the array.

.2 It can be important to locate the DC disconnect next to the inverter for reasons of system maintenance and safety.

.3 The DC disconnect is required to have an appropriate DC current rating. Its rating may also govern how it is connected to the system's wiring.

.10 GRID-DEPENDENT INVERTER

.1 A grid-dependent DC to AC inverter is at the heart of a grid-dependent PV system. This inverter type is termed a “solar-powered inverter” because its DC source is a PV system. It includes specific characteristics unique to operating a PV array and that are different than in a battery-powered inverter whose DC source is a battery bank.

.2 The inverter shuts down at night, starts in the morning, electrically tracks the array's maximum power point to keep it operating as efficiently as possible, turns off during electrical outages, and turns on 5 minutes after an outage ends. These inverters are current sources that inject current into an existing voltage waveform supplied by the local Wires Service Provider.

.3 The inverter is designed specifically for connection to the local electrical distribution system and can manage the electrical characteristics of an electrical outage.

.1 It turns itself off when it detects any grid electrical conditions that are greater than a maximum set voltage, less than a minimum set voltage, greater a maximum set frequency, or less than a minimum set frequency, or if it detects that an outage has occurred.

.2 It incorporates an anti-islanding mechanism that tests the grid continually to determine whether a power outage has occurred.

.3 The system is fail-safe.

.4 The inverter is required to be compliant with Clause 15 of Canadian Standards Association standard C22.2 No. 107.1.

.1 Its documentation or label needs to show that it meets the CSA performance standard C22.2 No. 107-01 for grid-connection. This

CSA standard ensures that the inverter will properly shut down during a grid outage.

.5 The inverter needs to meet the requirements for a grid-connected inverter as specified by the local Wires Service Providers.

.6 The inverter usually has a DC ground-fault protection device built into it. This detects whether there are any faults (or short circuits) from the array to ground, shunts the fault to the ground, and disables the array until the fault has been corrected. If such a protection device is not built in, then it is normally included in the system as a separate device.

.7 The inverter typically has a power factor of one without using external reactive power compensation devices.

.8 The inverter is selected such that its output voltage matches the building's voltage without any external transformer.

.9 The inverter is typically mounted on a wall.

.10 Manufacturers typically test and warrant their inverters to operate properly between air temperatures ranging from -20°C to +45°C, as indicated in the inverter's brochure and installation manual. The inverter needs to be located in a space whose temperature will not go outside of the manufacturer's temperatures ratings. Any concerns about whether an ambient temperature outside of the rating is acceptable should be directed to the manufacturer for written confirmation.

.11 The inverter typically has a warranty of between 5 and 10 years.

.11 BATTERY BANK

.1 A grid-dependent solar PV system has no electrical storage component, such as a battery bank.

.2 It effectively “stores” its excess electricity in the grid. Another way to look at this is that the solar electricity produced is stored in the form of the energy source that it displaces, such as unused coal, natural gas, stored hydro or nuclear.

.12 OVERCURRENT DEVICES

.1 Over-current protection is required on DC circuits.

.1 Array over-current protection is sized to protect the wiring on the DC side no matter what the source of fault current.

.2 Series fuses are required in PV source circuits if the available array fault current is greater than the PV modules' series fuse rating or the current-carrying capacity of the PV source circuit conductors.

.1 Fuses don't need to be used in arrays with only two strings because a string will only be exposed to a current of I_{SC} x (n-1) plus whatever can be delivered from the grid (which is zero if an inverter cannot pass grid-AC current to the array). Therefore a string fuse needs to be 125% x I_{SC} x (n-1).

.2 The "bottom" of a shorted string (the part of the shorted string connected to the negative terminal) will only produce 125% x I_{SC} into the fault. The top of the shorted string (the part connected to the positive terminal) will be subjected to

125% x I_{SC} x (n-1) from the rest of the array minus the fact that it is trying to produce 125% x I_{SC} itself in the forward direction. The top of the shorted string therefore is only subject to 125% x I_{SC} x (n-2).

.2 Fuses are required on the PV output circuit if the inverter is capable of backfeeding from the AC side onto the DC side.

.3 A surge suppression device is usually required on a system in order to help protect against damage from lightning. Some inverters already include this device.

.13 AC DISCONNECT

.1 An AC disconnect switch is positioned between the inverter and building's breaker panelboard. It serves to disconnect the inverter from the breaker panelboard.

.2 If the breaker panelboard to which the PV system is connected is out of sight of the inverter or a long distance away, it can be important to locate an AC disconnect next to the inverter for reasons of system maintenance and safety.

.3 The Canadian Electrical Code now requires a visible-break AC disconnect switch only if it is required by the local Wires Service Provider.

.14 AC BRANCH CIRCUIT BREAKER

.1 The PV system is connected to the building loads through a back-fed AC branch circuit breaker. It is acceptable to back feed this breaker only if the breaker does <u>not</u> have markings of "line" and "load" written on it.

.15 INSTRUMENTATION

.1 Metering a PV system can be very important, especially when there is such little experience with them and little understanding of how they operate.

.1 The simplest metering is a manually-read kWh energy meter located on the AC side of the inverter. This meter measures the system's electricity production.

.2 A second level of metering is to install a bi-directional cumulative meter at the site's service entrance. This meter separately measures the amount of electricity imported and exported.

.3 From these two meters, the electricity consumed by the site can be calculated by doing an energy balance:

- PV electrical energy generated + electrical energy imported from the grid = electrical energy consumed + electrical energy exported to the grid, or
- $E_{PV} + E_{imports} = E_{loads} + E_{exports}$.

.4 Almost any size PV system on a house will export electricity on any sunny day of the year.

.5 If a small PV system is connected to a large consumer of electricity then it is unlikely that any electricity will be exported, thus no special metering is needed.

.2 Further instrumentation can be installed to measure solar radiation, DC voltage, DC current, and active and reactive AC energy so that the production, performance, operation and efficiency of each of the system's components can be calculated. This can get expensive very quickly and so needs to be designed and implemented well.

.3 Modern inverters can measure their own performance along with environmental data and can send these data onto an internet web site.

1.8 Approvals

.1 REGULATORY

.1 The regulatory approvals process includes approvals for developing, constructing and operating the PV system, plus payment for any electricity exported onto the electrical distribution system.

.2 Step-by-step instructions for proceeding through Alberta's simplified micro-generator regulatory approvals process are covered in the document "Alberta Solar Showcase Interconnection Approvals Process".

.2 SAFETY CERTIFICATION

.1 As with all electrical products, all components of a solar PV system are to be certified to Canadian standards and contain nameplates with a certification label from among one of those listed in Alberta's most recent Electrical Information Safety Bulletin STANDATA LEG-ECR-2 (or equivalent in other provinces).

.1 A "Special Inspection" label certifies that the equipment has been field tested for fire and shock hazards. This is a sufficient inspection label for all electrical equipment, but it is not a sufficient label for a grid-connected inverter because an inverter needs a performance label in addition to a fire and shock hazard label.

.2 Grid-connected solar PV systems are required by international and Canadian standards to cease to energise the grid during a grid outage. This shut down process is called "anti-islanding" and is of utmost importance to safety and the local Wires Service Provider. There are many methods available to ensure anti-islanding. The result of the work to develop anti-islanding technologies is that islanding no longer amounts to a technical safety issue.

1.9 Documentation

.1 The purpose of documentation is to increase the capacity of building operator personnel on PV technology, and the capacity of PV system Supply Contractors in relating to building operators.

.2 PV systems are expected to have a lifetime of decades, and accommodate building maintenance or modifications near the array or inverter likely at some point.

.3 The ownership of a system may change, particularly for home-mounted systems.

.4 Only by the provision of adequate documentation at the outset can the long-term performance and safety of the PV system and modifications on or adjacent to the system be ensured.

.5 Documentation is also important for awareness, training, maintenance, and system upgrades over the years.

.6 Documentation needs to consist of information covering system design, configuration, installation, operation, maintenance and performance measurement.

.7 The operation and maintenance (O&M) manual needs to be considerate of Owners and building operators both now when the system is installed and in the future long after current personnel cease to be available. These people have much experience with buildings and their electrical and heating systems, but likely no experience with PV systems.

.8 The contents of the O&M manual as required in the specifications are based on standard building equipment and O&M considerations, with the goal of answering questions that will likely be asked. As a result, if an item in the specifications for the manual is obvious, "not required", or "same as something else", then this should be stated. The point is that building operators will be reading the manual based on their experience, which likely does not include PV, and so will be asking these questions. If the manual answers the questions then people will be more comfortable with the technology.

.9 The project's site documentation needs to show:

.1 The location and address of the building or site on which the PV system is mounted;

.2 The location on the building or the building site where the PV array is located;

.3 The location of the inverter and the disconnect switches inside the building or site;

.4 The location of the breaker panelboard in the electrical room where the PV system's electrical connection will be made to the building or site wiring;

.5 Distances from the PV array to the DC disconnect to the inverter to the building's breaker panelboard;

.6 Any major array or inverter mounting decisions; and

.7 Photos of the south side of the building, the southern solar exposure from the array location, the array location and attachment to the building, along the wiring runs, the wall construction and details showing wire penetration and attachment, the disconnect and inverter location and attachment, the electrical breaker panelboard and any metering.

1.10 Training

.1 Building operators need to be trained on the operation and maintenance requirements of PV systems in order that they can maximise its benefits and minimise any costs throughout its life cycle.

1.11 Design

.1 There are several important PV-unique details to understand in order to design an effective grid-dependent PV system, a brief list of which includes the effects of

temperature on PV modules, the use of DC fuses, the effects of shading and the interplay between the array and the inverter.

.2 Design considerations for grid-connected systems involve matching the PV modules electrically to the inverter, physically to the dimensions and appearance of the available building or site space, and financially to budgets.

.3 There are some public sources of PV system design information available, along with recommendations borne from system experience.

.4 The basic principles to follow when designing a PV system are:

.1 Size and orient the PV array to provide the required electrical power and energy, to fit with the inverter's electrical requirements and the required visual appearance.

.2 Locate the array to minimize shading from foliage, vent pipes, buildings and adjacent structures.

.3 Ensure the area of the array installation site is capable of handling the desired array size.

.4 Verify that the array attachment structure is capable of handling additional weight of the array. Augment the structure as necessary.

.5 Specify sunlight and weather resistant materials for all outdoor equipment.

.6 Design the system in compliance with all applicable building and electrical codes and local utility interconnection requirements.

.7 Design the system with a minimum of electrical losses due to wiring, terminations, diodes, fuses, switches, inverters, relays and transformers.

1.12 Choosing The Location Of PV System Components

.1 There are three main decisions to be made in siting a solar PV system: determining the location of the array, the location of the switchgear and inverter, and the routing of the cabling between the array and the switchgear and inverter.

.2 ARRAY LOCATION

.1 Mount the array in such a location, tilt angle, and orientation angle as to maximise the benefits to the PV system's stakeholders. See Article 1.19 for details on benefits.

.2 The Owner typically decides whether the array is installed on the roof, the wall, the ground, or another building structure such as an overhang, canopy, awning, entranceway, display sign or window.

.3 The building may be new, existing, or non-existent.

.4 The array location needs to:

.1 Maximise the everyday visibility of the array to the system's stakeholders.

.2 Minimise the amount of shading on it between 09:00 to 16:00, including shading from foliage, buildings, vent pipes, poles, buildings and other objects and structures.

.3 Consider the length of the wiring run from it to the switchgear/inverter, and from the switchgear/inverter to the building's breaker panelboard.

.5 In a roof-type installation, the PV array is mounted onto a roof structural support frame and attached into the roof deck structure.

.6 In a wall-type installation, the PV array is fixed onto a wall structure at angles ranging from vertical to 20°, and could appear as a sloped awning-type structure.

.7 The tilt angle required to produce the maximum annual amount of electricity depends on the latitude of the location in which the array is mounted.

.1 The optimum tilt angle can be found using Natural Resources Canada's RETScreen software (www.retscreen.net).

.2 The reduction in electricity production in Alberta for tilt angles deviating from the optimum angle is typically less than 10% when tilt angles range between the site latitude minus 35° to latitude plus 26°.

.3 Tilt angles are always measured from the horizon.

.8 The east-west orientation angle (called the azimuth angle) required to produce the maximum annual amount of electricity equals due south throughout Alberta.

.1 The reduction in electricity production for azimuth angles deviating from the optimum angle is typically less than 10% when azimuth angles range between south-east to south-west.

.2 Note azimuth angles can be measured from north or from south, and need to be clear on how they are measured.

.3 Note only use azimuth angles that are true and not magnetic, *i.e.*, true north, not magnetic north. For the location's magnetic declination and for determining the difference between true north and magnetic north, see (http://geomag.nrcan.gc.ca/apps/mdcal_e.php).

.9 Figures 2 and 3 show examples of a typical roof-mounted array.

Figure 2. Front of a roof-mounted PV array

Figure 3. Rear of a roof-mounted PV array

.3 SWITCHGEAR AND INVERTER

.1 The switchgear and inverter are usually located near each other in a mechanical room or electrical room. They can also be located, when

displayed in an attractive manner, in a lobby, foyer, hallway or other publicly-accessible space frequented by the Owner's stakeholders.

.2 It can be important to locate both the DC and AC disconnects next to the inverter for reasons of system maintenance and safety.

.4 CABLE ROUTING

.1 The routing of the wiring from the array to the switchgear/inverter, and on to the breaker panelboard needs to be selected to reduce its length and thus the energy lost in the wiring, plus the costs of cable purchase and installation.

1.13 Quality Installation

.1 Attention to installation detail is critically important to the success acceptance of PV technologies. Recent studies have found that 10-20% of new PV installations have serious installation problems that result in significantly-decreased performance. In many of these cases, the performance shortfalls could have been eliminated with proper attention to installation details.

.2 Any building penetrations are to be done with great care to avoid significant moisture problems. As a result it is advised that:

.1 A qualified Roofing Contractor install all roofing and building envelope penetration and all connections to the roof and building envelope structure.

.2 If the PV system is to be installed on a roof, the Roofing Contractor should be a professional roofing contractor who is a member in good standing of the provincial roofing contractors association.

.3 The basic steps to follow when installing a PV system are:

.1 Ensure the installation site is capable of handling the space required by the array and switchgear/inverter.

.2 Verify that the array attachment structure is capable of handling the additional weight of the PV array. Augment the structure as necessary.

.3 Properly seal any array attachment structure penetrations with roofing-industry approved sealing methods.

.4 Install equipment according to manufacturers' specifications, using installation requirements and procedures from the manufacturers' installation guides.

.5 Properly bond the system components to ground to reduce the threat of shock hazards and induced surges.

.6 Check for proper PV system operation by following an approved checklist procedure.

.7 Have final inspections completed by the local electrical inspector.

.4 Helpful recommendations:

.1 Check PV modules visually and check the open circuit voltage and short circuit current of each module before mounting onto the structure.

.2 Use only as many attachment points and roof penetrations as necessary for structural loading concerns. The number of attachment points and

structural requirements of the roof are to be specifically identified in the drawings.

1.14 Commissioning

.1 It is advised to perform a standard commissioning procedure.

.2 The goal of the commissioning is to:

.1 Provide effective documentation to the Owner;

.2 Assist in the verification and inspection of the PV system after installation and for subsequent re-inspection, maintenance or modifications.

.3 Commissioning:

.1 Determines whether all the components of the PV system have been delivered and are working as nominally intended;

.2 Ensures that key system information is readily available to the Owner, inspector and maintenance personnel.

.3 Includes commissioning tests, inspection criteria and documentation expected to verify the safe installation and correct operation of the system.

.4 Typically, the Installation Contractor verifies that the system has been installed according to the manufacturers' procedures.

.5 Obtaining extremely accurate performance data for commissioning purposes is difficult and requires expensive test equipment. Fortunately, it is not necessary to measure the performance with extreme accuracy. A system can be checked with common test equipment to verify proper installation and performance. A key to keeping the testing simple is to conduct the tests on cloudless days because clouds can cause fluctuations that confound the measurements and their evaluation.

1.15 Maintenance

.1 SOLAR PV ARRAY

.1 The array is normally maintenance free. Maintenance on the array may include as an option:

.1 Washing it in the summer if it gets too dirty.

.1 The amount of dirt building up on an array depends on how close it is to the ground, how close it is to unfinished ground surfaces and to roads, and the amount and frequency of rain.

.2 An option is to allow it to get dirty and then be cleansed automatically by gravity-fed atmospheric-sourced Renewable Ambient-Imposed Natural water (otherwise known as rain).

.2 Pushing snow off in the winter or letting snow accumulate until it sloughs off in warmer weather, such as in summer.

.2 SOLAR PV MODULE MOUNTING RACK

.1 No maintenance is typically required if the rack is at fixed tilt and azimuth angles.

.2 A solar tracking system can require maintenance.

.1 Seasonal tracking requires manual adjustment of the rack tilt angle at least twice a year.

.2 Other tracking systems may need adjustments and maintenance on the tracking motor, runways and tracking arms.

.3 WIRING AND CABLING

.1 Only normal wiring maintenance is usually needed.

.2 Wiring exposed to sunlight should be checked every few years to evaluate any sunlight damage.

.4 DIODES

.1 No maintenance is typically required.

.2 If there are fault issues with the modules, then the diodes should be checked for continuity.

.5 DC DISCONNECT

.1 No maintenance is typically required.

.2 If dark streaks are noticed on the inside, then this means that electrical arcs have occurred during operation of the disconnect. This may mean that the disconnect is not suitably rated for the array current.

.6 GRID-DEPENDENT INVERTER

.1 Maintenance on the inverter can amount to:

.1 Making sure that dust, papers, or other objects do not accumulate and reduce the effectiveness of any heat radiating fins on the inverter's top surface; and

.2 Replacing electronic parts if they fail.

.7 OVERCURRENT DEVICES

.1 If the system experiences a lightning strike, then the surge suppression device needs to be checked to evaluate its replacement.

.2 Any DC fuses should be checked if the PV system performance suddenly changes.

.8 AC DISCONNECT

.1 No maintenance is typically required.

.9 AC BRANCH CIRCUIT BREAKER

.1 No maintenance is typically required.

.10 REGULATORY APPROVALS

.1 If the building is sold or any major modifications are made to the PV system, then the Wires Service Provider needs to be notified. See the Alberta Solar Showcase Interconnection Approvals Process document for details.

.11 DOCUMENTATION

.1 It is very helpful to keep a monthly log of the PV system's meter and other performance data and its calculated performance indices. This is to detect major changes in system operation due to the malfunction of equipment.

.12 TRAINING

.1 Current and subsequent building operators need to be trained in how the system performs and is maintained. O&M manuals are set up to provide this to normal building operator standards.

1.16 Choosing a Design Contractor

.1 The PV system Design Contractor can be a qualified PV system Supply Contractor or an electrical engineer.

.2 It is highly advised to choose a Design Contractor that is able to show their qualifications and experience in the type of PV system being designed.

1.17 Choosing a Supply Contractor

.1 Some Owners wish to support Canadian manufacturers of PV system components. Though this is good, it greatly restricts the choices of PV modules and supply chain.

.2 Manufacturers of PV modules are based in America, Australia, Canada China, France, Germany, Great Britain, India, Japan, Netherlands and Spain (and likely more) with factories around the world. Canada has three PV module manufacturers in 2008, though likely only one would be producing products that would be suitable for most grid-connected systems.

.3 Manufacturers of common PV module mounting racks are based in America. Some local Supply Contractors also manufacture their own simple aluminum struts.

.4 Manufacturers of inverters are located in America, Austria, Canada, Germany and Japan. Their product line may or may not be suitable for the Owner's system due to the inverter power capacity or its voltage output.

.5 Most manufacturers of PV system components have a dealer network in Canada.

.6 It is highly recommended that Supply Contractors of PV modules, PV module mounting racks, unique PV combiner boxes (if required), and inverters be Canadian-based dealers that are members in good standing of the Canadian Solar Industries Association (CanSIA).

.1 Canadian-based Supply Contractors

.1 Purchasing products directly from Supply Contractors outside of Canada will not necessarily provide products that are legally certified for Canada and thus permitted to be imported into Canada. It is not legal to sell or install electrical equipment or hardware that is not certified to Canadian standards. Mistakes with legal certification cause many issues when the system is installed and inspected.

.2 Local Supply Contractors often give the best pricing.

.2 Membership in CanSIA:

.1 Indicates the value that a Supply Contractor places in openness, credibility, trust, ethics, respect, integrity, and scrutiny before its own peers. These are the hallmarks that show that an industry and its members are striving to serve society well.

.2 Shows that the Supply Contractor is interested in the long-term health of the whole industry not just her own company.

.3 Helps the industry become stronger as it works to reduce the obstacles to the development of PV technologies.

.4 Reduces the risk of project problems because the Supply Contractor is required to submit to CanSIA's Code of Ethics.

.5 Does not otherwise indicate technical qualifications or competency.

.7 All other PV system components including wiring, disconnects, breakers, conduit, fittings and metering are standard electrical products and can easily be purchased from many Canadian electrical Supply Contractors.

.8 It is advised to verify before purchasing that all PV system equipment contains nameplate labels showing that they are certified to Canadian standards as per Alberta's most recent Electrical Information Safety Bulletin STANDATA LEG-ECR-2 (or equivalent in other provinces) as described in Article 1.8.2 in this Section.

1.18 Choosing an Installation Contractor

.1 Since a PV system is an electrical system, only master electricians (or homeowners) are permitted to be responsible for its electrical work and thus to acquire its electrical permit.

.1 Some master electricians permit experienced people who are not electricians to mechanically and structurally install the PV modules (but not electrically install them), which is acceptable.

.2 As a requirement of the Canadian Electrical Code, it is not legal for a PV-equipment Supply Contractor (if they are not also a master electrician) to be responsible for a PV system installation other than one with very low voltage and very low power capacities.

.3 Some master electricians make arrangements with other non-master electricians to do the electrical work though the master electrician does not check it. This sometimes results in shoddy and unsafe electrical work.

.2 In this early stage of PV system development, it is advised to have a qualified electrical contractor work as a close team with a qualified well-established PV system Supply Contractor. In this way, the team has both competency in standard electrical work and competency in solar PV technology.

.3 If an electrical contractor has several years of experience installing a variety of types of solar power systems, and is an authorised dealer of a PV system Supply Contractor, then the electrical contractor likely already has the necessary qualifications to supply (without the PV component Supply Contractor being closely involved) as well as install. CanSIA membership requirements apply.

.4 It is highly valuable that someone on the installation team has installation experience or certified PV technician training such as follows. People with these certificates, however, are presently not common.

.1 Successful completion of a PV installation training course of at least 30 hours

.2 PV Technician Certificate from Seneca College, Toronto (www.senecac.on.ca)

.3 Solar PV Installer Certification from the North American Board of Certified Energy Practitioners (NABCEP) (www.napbcep.org)

.4 PV Design & Installation course from Solar Energy International, Colorado (www.solarenergy.org)

.5 Since a PV system is an electrical system, an electrical permit is required for it to be installed.

1.19 PV System Benefits – Determining And Maximising Them

.1 Grid-connected solar PV systems can provide the following benefits. The focus of the project needs to understand the priorities of the Owner in these areas, so that these benefits can be maximised.

.1 ELECTRICAL BILLS:

.1 Reducing utility electrical energy charges due to the amount of electricity produced;

.2 Reducing utility peak electrical demand charges when the peak loads coincide with the peak PV production;

.3 Being able to sell excess electricity to the grid;

.4 Being able to sell emission reductions.

.2 SECURITY:

.1 Knowing that the electricity is inflation-secure;

.2 Having continuous electricity through outages;

.1 Outage security only arises if the system includes electricity storage means such as a battery bank.

.3 ENVIRONMENT:

.1 Reducing the building's environmental footprint;

.2 Being able to be certified by Environment Canada's EcoLogo™ programme as being emissions free, and so able to meet personal, corporate, or organisational emission reduction policies.

.4 ELECTRICAL INFRASTRUCTURE:

.1 Reducing stress on utility electrical lines and equipment;

.2 Reducing electrical generation overcapacity.

.5 RELATIONSHIPS:

.1 Helping to meet the goals of environmental policies including sustainable development, leadership, and the awareness of staff, general public, and Supply Contractors;

.2 Providing a prestigious environmental image to enhance lifestyle buildings, environmental programmes, and product marketability;

.3 Providing a highly visible method of sending clear messages regarding corporate, school or government commitment and leadership towards environmental policies and action;

.4 Status, peer prestige.

.6 PERSONAL:

.1 Being the first on the block with a solar PV system;

.2 Satisfying the quest for personal interest and validation;

.3 Providing additional fun and meaning in life.

.7 ECONOMIC DEVELOPMENT:

.1 Providing a first-hand touchable system to train the public and market PV technology;

.2 Helping students learn about new energy technologies and so prepare them to face the future energy and environmental opportunities;

.3 Helping to meet the goals of technical development policies including awareness of staff, general public, and Supply Contractors, and development of industrial manufacturing and supply capacity;

.4 Preparing the company for solar market opportunities, training staff;

.5 Providing a tool to learn about the performance and technical facets of PV;

.6 Providing a tool to identify and resolve PV codes, regulations, permits, metering, and technical interconnection barriers;

.7 Providing a tool to identify new PV markets, growth potential, and obstacles to market penetration.

.2 Benefit-Value Analysis

.1 Each of these benefits has a monetary value that accrues to the Owner and to the system's other stakeholders. The value of the benefits depends on their policies and choice priorities.

.2 A benefit's value can be determined by performing a Benefit-Value Analysis, which includes how much the benefit is worth and what is the likelihood that that benefit will occur.

.3 A Benefit-Value Analysis feeds into Full-Cost/Full-Benefits calculations that determine true economic payback and return on investment indicators.

.3 Stakeholders

.1 The identification of stakeholders is an important tool that can be used to determine and maximise the benefits of a PV system.

1.20 Definitions [1]

.1 Attachment structure

The part of a building's structural member to which a PV component will be attached. For the array, this typically includes a roof or wall, but could also include overhangs, canopies, awnings, entranceways, signs, barriers, decorative or other architectural features, piles or other foundations in the ground, or any building-integrated element or product such as windows, cladding, or spandrel members.

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[1] Partially excerpted from IEC Technical Specification 61836, *Solar Photovoltaic Energy Systems – Terms, Definitions and Symbols*.

.2 Azimuth angle

Colloquially considered to be the east-west orientation angle of a PV module or array. Measured from due south or due north.

.3 Blocking diode

A diode connected in series with a PV string to block reverse current into the string. These have disappeared from common practice.

.4 Bypass diode

A diode connected in the forward current direction across one or more PV cells. It allows reverse-voltage PV module current to bypass the cells and prevent hot-spot or hot-cell damage resulting from the reverse voltage biasing from the other cells in that module.

.5 Capacity factor

The equivalent average portion of time in which an electricity generation plant operates at its rated generating capacity. Units: %.

Large fully-loaded electricity generating plants have annual capacity factors ranging up to 90%. Solar PV systems cannot have an annual capacity factor of more than 50% because solar radiation is typically not available more than 50% of the time. The annual capacity factor of PV systems is an average of 10% to 14%, ranging from 5% to 30% throughout the year.

.6 Commissioning

A systematic quality process of ensuring that all systems and components perform and interact according to the owner's requirements as described in the project contract documents.

.7 Contractor

The person or company that has a contract to design, supply, install and/or commission a work, system or piece of equipment.

.8 CSA

Refers to the Canadian Standards Association.

.9 Export

To send electricity from a consumer site onto the electrical distribution system of a local Wires Service Provider. The export of electricity is independent of being paid for this electricity.

.10 Grid-connected inverter

An inverter that is connected to and operates in parallel with an electric utility. Also known as a grid-intertie or a grid-tied inverter. It may or may not use an energy storage device.

.11 Grid-connected PV system

A PV system that is connected to and operates in parallel with an electric utility. Also known as a grid-intertie or a grid-tied PV system. It may or may not contain an energy storage device.

.12 Grid-dependent inverter
A type of grid-connected inverter that depends on the availability of the electric utility's voltage waveform to initiate and continue the inverter's operation. A grid-dependent inverter is commonly a current injection device that injects current into an existing voltage waveform. These are solar-powered inverters and are different from battery-powered inverters. No energy storage devices are used by this inverter.

.13 Grid-dependent PV system
A type of grid-connected PV system that utilises a grid-dependent inverter as its sole DC to AC conversion device. No energy storage devices are contained in this PV system.

.14 Import
To bring electricity into a consumer site from the electrical distribution system of a local Wires Service Provider.

.15 Installation site
The location in the attachment structure or site plan where components of the PV system will be mounted.

.16 Inverter
An electronic device that converts DC electricity into AC electricity.

.17 MC Connector
Refers to a Multi-Contact brand of electrical connector.

.18 Photovoltaic array
A mechanically integrated assembly of PV modules and their supporting structure. An array does not include its foundation, tracking apparatus, or thermal control, and other such components.

.19 Photovoltaic cell
The basic device that produces DC voltage by the absorption of light radiation.

.20 Photovoltaic effect
The effect where DC voltage is produced by the absorption of light. The result is the direct conversion of the energy in photons of light into electricity.

.21 Photovoltaic module
The smallest complete environmentally protected assembly of interconnected PV cells.

.22 Photovoltaic string
A number of PV modules connected in series.

.23 Photovoltaic system
An assembly of components that produce and supply electricity sourced from light energy.

.24 PV

A common verbal and print abbreviation for technology where its source of energy is derived using the photovoltaic effect. Photovoltaic and PV are synonymous.

.25 Site plan

A drawing of the PV system site showing its equipment and structural layout.

.26 Solar energy

The energy in the photons that comprise solar radiation.

.27 Solar irradiance

The amount of solar radiation.

.28 Solar radiation

The stream of photons emanating from the sun.

.29 Solar PV

A more formal reference to PV. Synonymous with PV.

.30 Stakeholder

Any person or organisation that has a relationship with the project. This relationship can be for many reasons, including financial, social, technical, or personal, as a Supply Contractor, a technical trade, a professional, or regulatory.

.31 Standard Test Conditions

Internationally accepted reference values of in-plane solar irradiance ($G_{I,ref}$ = 1 000 W·m^{-2}), photovoltaic cell temperature (T_c = 25°C), and air mass (AM = 1.5) to be used during the testing of any PV device.

.32 Submittal

Information that is submitted to the Owner or Design Contractor as a deliverable or proposal. Submittals include manuals, documentation, graphics, catalogues, shop drawings, illustrations, schedules, performance charts, instructions, brochures, and diagrams.

.33 Switchgear

A group term referencing DC disconnects, AC disconnects, and breakers.

.34 Tilt angle

Colloquially considered to be the up-down angle of a PV module or array as measured from the horizon.

.35 UL

Refers to Underwriters' Laboratories Inc., an independent, not-for-profit product safety certification organisation headquartered in Illinois, America.

.36 ULC

Refers to Underwriters' Laboratories of Canada, an independent, not-for-profit product safety certification organisation, headquartered in Toronto.

.37 Wires Owner
The company that owns the local electrical distribution system. Wires Owners either offer their own Wires Service to their customers or contract out their Wires Service to a Wires Service Provider.

.38 Wires Service
The delivery of electricity from the transmission system to the load customer using a distribution system.

.39 Wires Service Provider
The company that operates the local electrical distribution system.

1.21 References

CAUTION – Use any non-Canadian references listed here with caution as they will be referencing electrical codes that may differ from the Canadian Electrical Code.

.1 Alberta Distributed Generation Interconnection Guide. 2002 July 16. Available from any Wires Service Provider in Alberta.

.2 Endecon Engineering. 2001. *Guide to PV System Design and Installation*. Report 500-01-020. California Energy Commission, Energy Technology Development Division. Sacramento, America. 40 pp. Download from (http://www.energy.ca.gov/reports/2001-09-04_500-01-020.pdf)

.3 Home Power Magazine. www.homepower.com. Phoenix, America.

.4 IEC 62246. 2005. *Minimum System Documentation Requirements for Grid Connected PV Systems*. Draft standard under development – not yet available. International Electrotechnical Commission. Geneva, Switzerland. 11 pp.

.5 Price, C.R. and E. Smiley. 2004. *PV and the Canadian Electrical Code*. PB020. Canadian Solar Industries Association with funding assistance by Natural Resources Canada. Ottawa, Canada. www.cansia.ca. $35 59 pp.

.6 Wiles, John. 2006. *Photovoltaic Power Systems and the 2005 National Electrical Code: Suggested Practices.* Southwest Technology Development Institute. New Mexico State University. Las Cruces, America. SAND 2005-0342-N. 147 pp.

.7 Wiles, John. 2004 March 25. "PV Modules and the Series Over-current Device". Phone: +1 505 646 6105.

PART 2 - PRODUCTS

Not used

PART 3 - EXECUTION

Not used

END OF SECTION

ALBERTA SOLAR SHOWCASE

www.lassothesun.ca

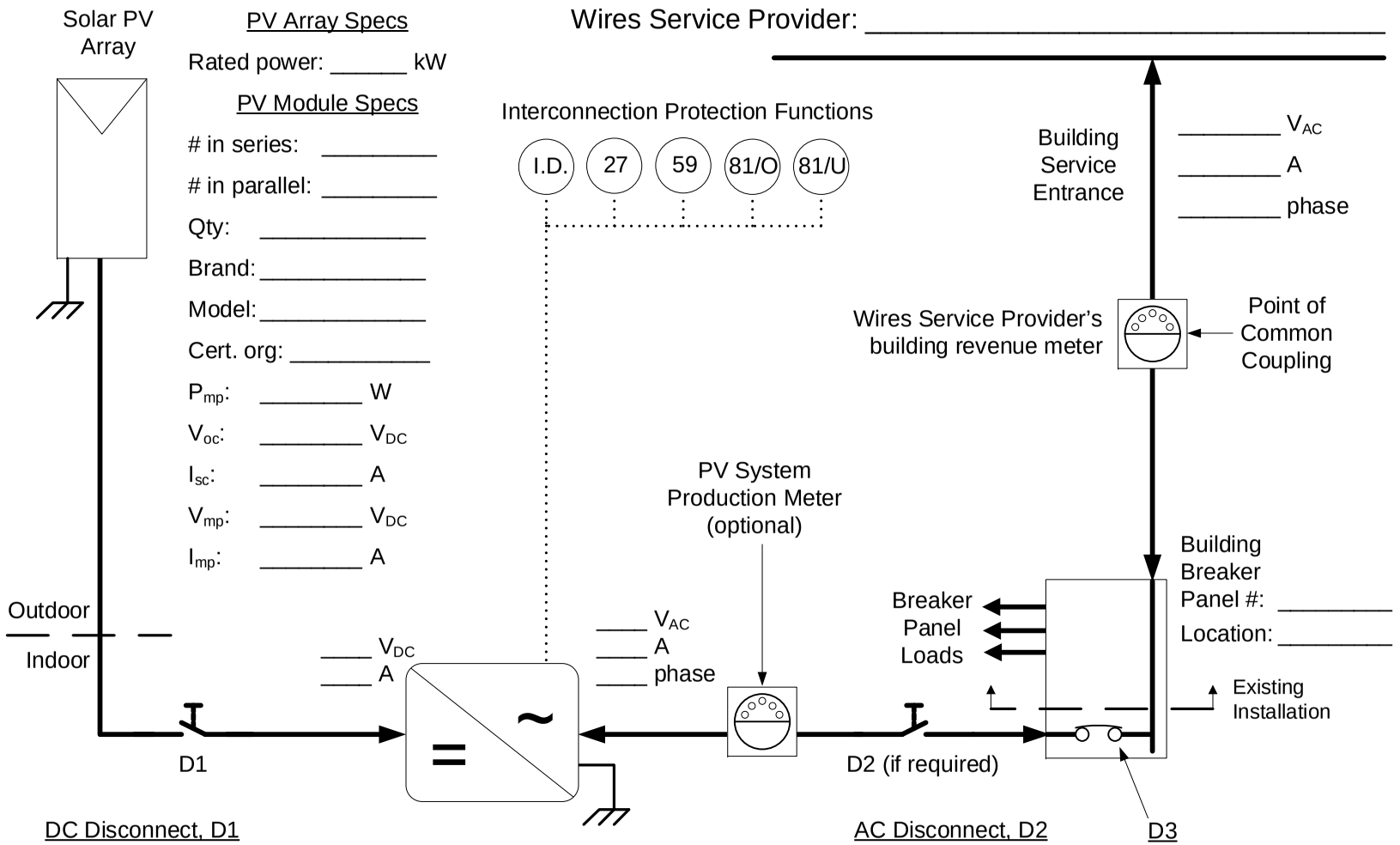
Solar PV System Drawings

Specifications for Grid-Connected Solar PV Systems

PROTECTION LEGEND:

27 - Under-Voltage
59 - Over-Voltage
81O - Over-Frequency
81U - Under-Frequency
I.D. - Islanding detection

Notes:
1. Wiring arrows indicate direction of power flow.
2. All components shall meet Canadian electrical equipment certification laws and contain nameplate labels indicating the Certifying Organization.
3. D2 to comply with CE Code 84-024 and requirements of Wires Service Provider.
4. Specific interconnection protection requirements are given by the Wires Service Provider and CSA C22.2 No. 107.1.



DC Disconnect, D1

Brand: _____
Model: _____
Rated voltage: _____ V_{DC}
Rated current: _____ A_{DC}
Cert. org: _____
Location: _____

Grid-Dependent DC-AC Inverter

Brand: _____
Model: _____
Rated power: _____ kW_{AC}
Cert. org: _____
Location: _____

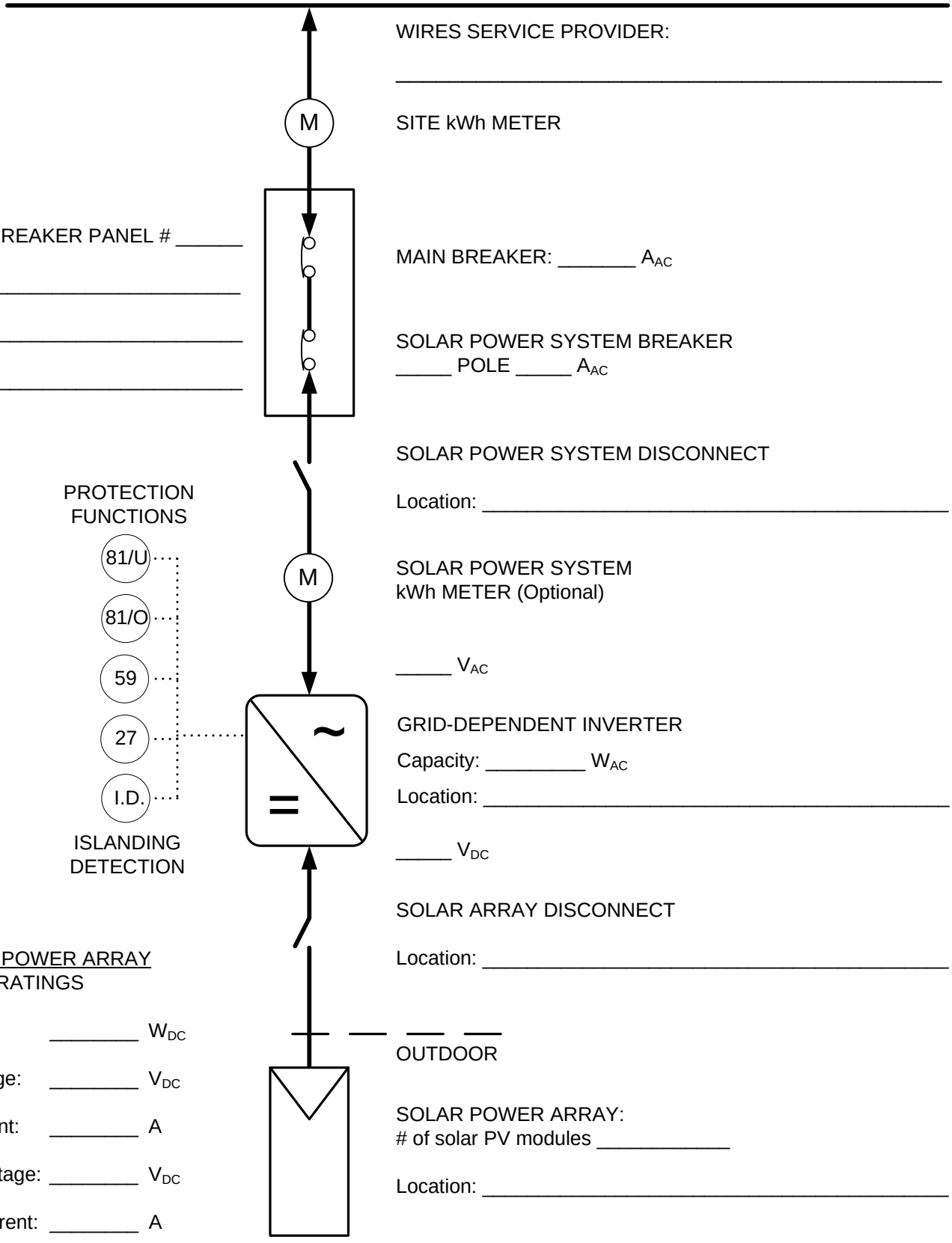
AC Disconnect, D2

Brand: _____
Model: _____
Rated voltage: _____ V_{AC}
Rated current: _____ A_{AC}
Cert. org: _____
Location: _____

D3

Breaker with no "line" and "load" markings
# of poles: _____
Rated current: _____ A_{AC}

	SINGLE LINE DRAWING	Submitted by:
	for Grid-Dependent, Solar PV Electric Power Production Equipment Interconnecting through the Wires Service Provider's Distribution Transformer	Date:
	This single line drawing is intended for use in permitting and interconnection approvals. It is not intended to be used for system design or installation. DRAWING NO. _____ REV _____ SCALE: NOT TO SCALE	Site Description:
		Site Location:



SOLAR POWER ARRAY RATINGS

Rated Power: _____ W_{DC}

Operating voltage: _____ V_{DC}

Operating current: _____ A

Open-circuit voltage: _____ V_{DC}

Short-circuit current: _____ A

Grid-Dependent Solar Photovoltaic (PV) System Interconnection Drawing

(as per CE Code 84-030(2))

Owner: _____

Address: _____

NOT TO SCALE DRAWING NO. _____ REV _____ DATE: _____