City of Edmonton

Solar Photovoltaic Program

Construction Guideline

Volume 3

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INTEGRATED INFRASTRUCTURE SERVICES
Facility Engineering Services –
Facility Planning & Design - Facility Infrastructure & Delivery

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INTENT OF USE

This guideline publication was developed for establishing guidelines for the City of Edmonton expectations for solar photovoltaic systems that are to be deployed on their facilities. The greatest care has been taken to confirm the accuracy of the information contained herein. The views expressed herein do not necessarily represent those of any individual contributor. Solar photovoltaic technologies continue to evolve, and deployment practices change and improve over time and it is advisable to regularly consult relevant technical standards, codes, and other publications on solar photovoltaic products and practices rather than relying on this publication exclusively. However, the City of Edmonton, authors, and members of the technical review committee, want to convey that this document does not constitute a project specific design. As such, no part of this guideline alleviates the responsibility of the professionals retained to design and construct specific solar photovoltaic projects from taking full responsibility and authenticating their designs in accordance with APEGA requirements.

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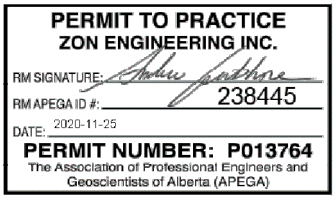
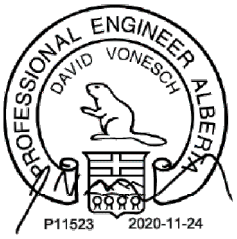
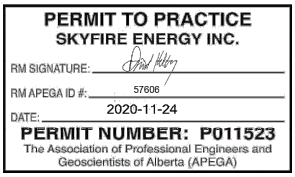
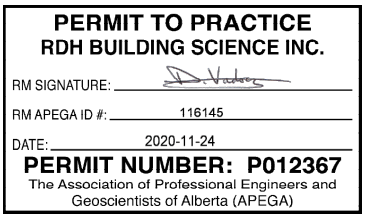
 2020-11-13 (Coordinator)		Responsible for all sections not specifically referenced by the following disciplines
		Sections 3.4, 4.1, 4.8, 4.9, 6.2, Sub-section 3.5.2, 3.5.3, 3.5.4, 3.6.6, 4.1.2, 4.1.7,
 November 16 2020		Sub-Section 3.5.5, 3.6.3, and 4.1.3 Section 6.1

Acronyms & Abbreviations

AC – Alternating Current
AEP – Alberta Environment and Parks
AESO – Alberta Electricity System Operator
AHJ – Authorities Having Jurisdiction
Al – Aluminum (conductor)
A/M/E/S – Architectural / Mechanical / Electrical / Structural Consultants
ANSI – American National Standards Institute
APEGA - Association of Professional Engineers and Geoscientists of Alberta
ARCA - Alberta Roofing Contractors Association
AUC – Alberta Utilities Commission
CAPEX – Capital Expenditure
CEC - Canadian Electrical Code
CoE – City of Edmonton
CRCA - Canadian Roofing Contractors Association
CSA – Canadian Standards Association
Cu – Copper (conductor)
DC – Direct Current
DG – Distributed Generation
EMT – Electrical Metallic Tubing
EoR – Engineer-of-Record
EPC – Engineer Procure Construct
EPS – Electrical Power System
FRP - Fiber Reinforced Polymer
GFI – Ground Fault Interrupter
IEEE - Institute of Electrical and Electronics Engineers
IFC – Issued for Construction
IFR – Issued for Review
ILR – Inverter Load Ratio (a.k.a. DC:AC Ratio)
IR – Infra-red
kW – 1000 watts (unit of power)
kWh – Kilowatt Hour (unit of energy)
kWp – Peak Kilowatt Rating (see STC below)
LOTO – Lock-out Tag-Out
MPPT – Maximum Power Point Tracker
MSDS – Material Safety Data Sheet
MLPE – Module Level Power Electronics
MW – one million watts (unit of power)
MWh – one million-watt hours (or one thousand kWh)
NBC(AE) National Building Code – 2019 Alberta Edition
NBC – National Building Code
NFPA – National Fire Protection Association
NRCA - National Roofing Contractors Association
OHS – Occupational Health & Safety
OPEX – Operating Expenditure
O&M – Operations & Maintenance
PVC – Polyvinyl chloride
PV – Photovoltaic (Solar Electric)
PPA – Power Purchase Agreement
PPE – Personal Protective Equipment
SCADA –Supervisory Control and Data Acquisition
SLD – Single Line Drawings
STC – Standard Test Conditions: 1,000 Watts per square meter solar irradiance, 25 degrees C cell temperature, air mass equal to 1.5, and ASTM G173-03 standard spectrum; units in DC Watts
UL – Underwriters Laboratory
UV – Ultraviolet Light (high energy component of the solar spectrum)
WSP – Wires Service Provider

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1 Overview

The objective of this construction guideline is to create a standard installation and safety practice for solar photovoltaic projects deployed on City of Edmonton facilities. This guideline is to be read in conjunction with all of the relevant codes and standards (per Section 2.0) and has been developed to consider not just initial installation, but also to include provisions for the safe and effective deployment and ongoing maintenance and operation of the solar photovoltaic assets.

1.1 Purpose & Scope

This document is intended to provide a guideline for use by either installation contractors professionals engaged by the city to design a solar PV project for tendering and/or contractors retained to provide a turn-key system. The contents of this guideline do not supersede any requirements of Authorities Having Jurisdiction (AHJ) but do provide, where possible, clarity as to what best practice deployment expectations the City of Edmonton has for its projects. This document is to be read in conjunction with *Volume 4 – Operations & Maintenance Guideline* for specifics around the ongoing maintenance best practices.

1.2 Definitions

- Photovoltaic Cells (Cells) – smallest commercial made device that directly converts the energy of light into electrical energy through the photovoltaic effect.
- Modules – are composed of cells connected in series and/or parallel which increases the voltage/current and is then laminated within or to glass. Commonly includes an aluminum frame, but some frameless modules are in use.
- Module Level Power Electronics (MLPE) – are devices (Optimizers, Micro-inverters) that can be incorporated into a solar PV system to improve its performance in certain conditions (especially where shade is present) and also be used to limit open circuit voltage and Isc potential.
- Strings – groups of modules connected in series to achieve the system operating voltage.
- Combiner/MPPT – groups of strings in parallel to achieve system operating current(s)
- Array – made up of mechanically contiguous groupings of modules that are in proximity or mechanically fastened together on the same structure.
- System – the collection of arrays that when connected electrically and comprise an entire solar photovoltaic system. The system typically includes both DC collection circuits and AC interconnection circuits. The arrays can be installed across different structures provided they are electrically common at one point.
- Solar Collector – more generic term typically used in zoning by-laws to refer to solar electric or solar thermal energy collection devices.
- Readily Accessible (based on CEC-2018-C22.1-18) – capable of being reached quickly for operation, renewal, or inspection without requiring persons seeking access to use tools, climb over or remove obstacles, resort to portable ladders, etc.
- Regularly Serviced Equipment – is equipment that will require at a minimum annual access to tighten connections, replace filters, or recalibrate. Examples include: Combiner Boxes, Inverters, switches and breakers etc.
- Infrequently Serviced Equipment – is equipment that requires access only if it is damaged, or non-functional. Examples include: Solar PV modules, Optimizers, microinverters etc.

- Exposed (based on CSA Z462 as applied to energized bare electrical conductors or circuit parts) – capable of being inadvertently touched or approached nearer than a safe distance by a person. This term is applied to electrical conductors or circuit parts that are not suitably guarded or insulated. E.g. bare terminals within equipment, unconnected PV module whips etc.

2 Referenced Standards

2.1 Construction Standards

2.1.1 Authorities Having Jurisdiction

- *Electric Utilities Act - Micro-Generation Regulation (Alberta Regulation 27/2008)*
- *AUC (Alberta Utilities Commission) Rule 007 – Applications for Power Plants, Substations, Transmission Lines, Industrial System Designations and Hydro Developments*
- *AUC Rule 012 – Noise Control*
- *AUC Rule 024 – Rules Respecting Micro-Generation*
- *Wildlife Directive for Alberta Solar Energy Projects (AEP Fish and Wildlife 2017 No. 5)*
- *EPCOR Customer Connection Guide – SECTION 9 (Micro-Generation)*
- *EPCOR Generator Interconnection Technical Guide for Edmonton*
- *Occupational Health and Safety (OHS)*
- *National Building Code – 2019 Alberta Edition (NBC(AE))*

2.1.2 Technical Standards

Canadian Standards Association (CSA)

- *CSA/ANSI C450-18, Photovoltaic (PV) module testing protocol for quality assurance programs.*
- *CSA-C22.1-18, Canadian Electrical Code, Part I*
- *CSA-C22.3 NO. 9-08 (R2015)- Interconnection of Distributed Resources*

Institute of Electrical and Electronics Engineers (IEEE)

- *IEEE1547-2018, Standard for Interconnecting Distributed Resources with Electric Power Systems*
- *1547-18, Standard for Interconnecting Distributed Resources with Electric Power Systems*

Underwriters Laboratory (UL)

- *UL - 6703 Standard for Connectors for Use in Photovoltaic Systems*
- *UL - 2703 Standard for Mounting Systems*

International Electrotechnical Commission (IEC)

- *IEC 62446 - Photovoltaic (PV) systems - Requirements for testing, documentation, and maintenance - Part 1: Grid connected systems - Documentation, commissioning tests and inspection*

2.1.3 Engineering Document Standards

- *Consultant Manual (Vol1 Design Process & Guidelines– v4.0)*
- *Consultant Manual (Vol2 – Technical Guidelines v4.0)*
- *Commissioning Consultant Manual (Vol 1 - Whole Building Commissioning Process & Guidelines v2.0)*
- *Commissioning Consultant Manual (Vol 2 - Building Envelope Commissioning Process v1.0)*
- *Design & Construction Standards (Volume 1 – General)*
- *Design & Construction Standards (Volume 7 – Power)*
- *City of Edmonton Solar Photovoltaic Program – Volume 1: Site Selection Guideline*
- *City of Edmonton Solar Photovoltaic Program – Volume 2: Design Guideline*
- *City of Edmonton Solar Photovoltaic Program – Volume 4: Operations & Maintenance Guideline*
- *City of Edmonton Solar Photovoltaic Program – Volume 5: Asset Management Guideline*

3 General

3.1 Safety

The City Manager *acknowledges as part of the Occupational Health & Safety program that all occupational injuries and illnesses can be prevented through an effective safety management system*. To this end, contractors shall take into account the following aspects as it relates to their activities during the installation phase of the project:

3.1.1 Health & Safety Orientation

All staff engaged in project work, whether at the tendering, construction or commissioning stage, are responsible for having completed the requisite City of Edmonton and employer health and safety orientation and training. Specific training (e.g. Working at Heights, Electrical Safety Awareness, etc.) will depend on the scope of their engagement.

3.1.2 Hazard Identification & Control

At the construction stage the specific controls relate primarily to administrative controls and Personal Protective Equipment (PPE) implementation. This primarily manifests into the following categories for solar photovoltaic projects:

- *Working at Heights* – during the installation stage every effort should be made to limit the travel near the roof edge. For sites where an adequate setback can be maintained, a “bump” line installed at least **2000 mm (6.6 ft)** back from the edge of the roof can provide a warning to workers that they are entering a restricted zone where appropriate travel restraint, or fall arrest equipment is required as noted in Part 9 161(3) of OH&S code. Similarly, guardrails that are properly secured / ballasted can ensure proper travel paths from the means of accessing the roof to the working zone.
- *Height/Weight of Equipment* – all equipment installations shall comply with the design documents and original equipment manufacturer’s installation manuals. Where field conditions require a variation, this must be reviewed with the Owner/Engineer-of-Record prior to proceeding. Attention should be paid to the means of supporting equipment that is installed in abnormal conditions (e.g. higher than standard or hung from surrounding structures).
- *Limits of Approach* – all equipment shall be placed in locations where the appropriate limited approach boundaries can be maintained (as defined by CSA Z462 from energized components). Signage, pylons and caution tape shall be put in place where necessary to prevent untrained workers from entering to within the limited approach boundary during all active wiring, connection, and commissioning activities.
- *Electrical Safety (e.g. shock and arc flash)* – All staff working on the project shall be adequately trained to ensure they are aware of both the electrical hazards, but also means of protecting themselves from this

work. Similarly, only qualified staff shall be involved in making electrical connections (including quick-connects). Where non-electrical workers are involved in the mechanical installation of equipment – it is imperative that they are supervised by a worker qualified to install the electrical aspects.

3.1.3 Fire Safety

The contractor shall ensure that a fire safety plan has been established for the site. This plan shall include signage for construction staff as to the means of exit/egress from the property, awareness as to the onsite fire alarm notifications and response, and communication protocols to advise building occupants of any fire events that may occur. A muster point shall be designated a safe distance from the facility and all onsite contractors and sub-contractors shall be aware of their responsibilities to attend to that point in the event of an emergency.

An appropriate ABC Fire Extinguisher shall always be accessible onsite, at both the array level, and at grade. Activities around energization of equipment for the first time shall be coordinated with 2-way radios to ensure there are observers at the point of energization and on the rooftop looking for any issues within the array at the time of energization.

Although this is not typically expected for most installations, where required the contractor shall obtain prior approval in accordance with City of Edmonton procedures for any Hot Work. The necessary permits shall be in place prior to the activity and building occupants shall be forewarned of any related work.

3.1.4 Environmental (e.g. spill management)

The contractor shall have a spill management program in effect throughout the duration of construction. The spill equipment (aka “kits”) and associated materials shall be appropriate for the extent of work and the possibility of any spill that could result from this work. Where practicable dry-type transformers shall be used to minimize the need for containment strategies.

3.1.5 Waste Management

To ensure a safe and orderly site, the contractor shall ensure waste material, from construction related activities, be collected on a daily basis, and all recyclable materials (e.g. cardboard, suitable plastics etc.) shall be recycled in accordance with the City of Edmonton waste management policies. All returnable items (spools, pallets, etc.) shall be returned by the contractor to the equipment supplier.

3.1.6 Toolbox Talk / Tailgate Talk

The contractor and associated sub-contractors shall institute a daily safety review, including overview of tasks, awareness hazards and reiteration of site-specific safety policies and procedures. This evaluation shall be documented as part of the safety program for the project.

3.1.7 Planned Safety Inspections

The contractor site safety manager shall conduct weekly Safety Inspections during the active construction stage. These inspections shall be documented, and infractions reviewed with the field staff and project team to enable alternative steps or measures to be undertaken.

3.1.8 Emergency Response Planning

The contractor shall ensure that emergency egress pathways are noted on their site signage. This is specifically required for rooftop layouts and ensuring that there is a clear means of egress from all areas with solar photovoltaic equipment. This information should be included in any site access documentation prepared for the project. Where possible multiple means of egress are ideal (e.g. temporary stair tower and the existing roof access).

3.1.9 Site Safety Data Sheet (SSDS)

For each project the contractor shall review the Site Safety Data Sheet associated with the project. This datasheet shall summarize the operational hazards including operating voltages, shock hazards, arc-flash classification, boundary and rating. Any revisions to the equipment, locations, or system configuration shall be updated on this document during the construction process. The final version shall be included in the Operations & Maintenance Manual and shall be kept on file by the facility. Refer to SCHEDULE 3 in *the CoE Solar Photovoltaic Program Volume 2 Design Guideline* for an example of the Site Safety Data Sheet (SSDS)

3.2 Site Access

Any personnel accessing a site during construction shall follow the same procedure. Access to any sites requires prior arrangements to be made through City of Edmonton staff contacts. It is the responsibility of all parties to ensure that they have completed the necessary safety orientation associated with the facility prior to arriving onsite or, if permissible, by the construction site supervisor immediately upon arrival. All personnel accessing the construction site shall sign-in with the construction site supervisor notifying them of the intent, expected duration, and emergency contact details. Before departing the site, all personnel shall sign-out and notify the construction site supervisor. The construction site supervisor shall co-ordinate all activities and visits with onsite facility staff.

3.3 Roof Access

For regular construction activities an approved means of enabling personnel to access the roof and materials shall be defined as part of the construction staging plan. All vertical access requirements shall be satisfied with an approved (and engineered) stair tower with railings along the exit ramp (at the roof level) or with a vertical lift, also equipped with appropriate offloading area. Temporary ladder access shall only be permitted for initial inspection, close-out or commissioning activities and not for active construction. The contractor shall ensure the site is substantially complete and make all efforts to have addressed all outstanding deficiencies prior to removing any construction access.

Figure 1 - Vertical Roof Access

3.4 Wall Access

For installation of wall mounted arrays, it is necessary that any method is properly suited to the application and installation as follows:

- Lift/Zoom Boom – in this case material handling must be appropriately coordinated, and this is likely only permissible for relatively small arrays that are not too high. In the case of mobile work platforms, attention shall be paid to the at-grade conditions, protection of any hardscape, and rehabilitation of any landscape.
- Scaffolding – Provided it is properly designed, installed, and approved by an engineer, scaffolding shall be an acceptable solution. Typically, a masonry style scaffolding is most appropriate to facilitate the movement and installation of materials.
- Mast Climbing Work Platform – for higher (defined as 3 stories or higher) installations a mast climbing work platform shall be used. Although this is a more involved solution, it can significantly increase worker effectiveness minimizing overall installation time. A swing stage may be an acceptable alternative, subject to city approval, and will depend on the anchoring means, and façade material.

3.5 Equipment Access

The ability to access both base building equipment and solar photovoltaic system equipment for routine servicing is a critical part of the installation. The intent is that these clearances are well defined within the design documents, however, it is the responsibility of all parties to ensure these setbacks have been maintained once the installation has been completed.

3.5.1 Base Building Maintenance Clearances

The area defined by the setback/clearance shall be free from all solar-project obstructions (including but not limited to) PV modules, racking, ballast, anchors and anchorage, wires, cables, raceways, etc. The only exception to this is where conductors must cross perpendicular to the area (e.g. exiting the roof). At any points where obstructions are over **600 mm (~2 ft)** wide and/or **450 mm (~1.5 ft)** high, and may intersect access pathways, they shall be furnished with a bridge to permit safe access. The summary of the minimum setbacks and clearances are detailed in *Table 3 – Setback Provisions* in the *CoE Solar Photovoltaic Program Volume 2: Design Guideline.*

3.5.2 Equipment Access & Pathways

Ensure all access routes to the mechanical equipment and utilities are maintained, if the PV module layout needs to be adjusted, ensure that the access provided within the design is not compromised. Specialized rooftop equipment such as roof top units, furnaces, etc. should be verified onsite to ensure that there is adequate access to fully remove components for replacement or servicing.

3.5.3 Servicing Considerations

There is a distinction between equipment that must be regularly serviced (i.e. devices with terminals that may require IR imaging or torque verification, etc.) and other components such as the modules, associated wiring, etc. which would only require access in the event of damage or failure.

3.5.4 Replacement Considerations

The installation onsite shall respect the design details, and opportunities to simplify the removal and replacement of rooftop mounted equipment, which should be considered during the installation. This could include ensuring wiring is accessible or that modules can be lifted without putting undue strain on the junction box or quick-connects.

3.5.5 Qualified Roofing, Wall Cladding Sub-Contractors, and Warranties

When retaining the services of a roofing sub-contractor (for roof mounted systems) or exterior wall cladding sub-contractors (for wall mounted systems) each sub-contractor should be qualified specifically for the work to be completed.

Where an ARCA warranty exists, the roofing sub-contractor should be a current member of the ARCA, and if the roof has pre-existing ARCA Warranty Certificate associated with the roof assembly, the same roofing sub-contractor who installed the roof assembly should be retained. This will help ensure continuity of any new or pre-existing ARCA Warranty and the continuity of workmanship and quality of the existing roof.

The wall cladding sub-contractor should be experienced with the cladding type affected by the PV array installation. The exterior wall cladding sub-contractor should also have experience with building enclosure rehabilitation or renewal and be aware of the environmental separation functions need for continuity of barriers (air, vapour, water resistive and thermal) in the exterior wall assembly.

3.6 Submittals

3.6.1 Owner Review

Owner review design packages/approvals to comply with section *2.2.1 listed in Vol 1 - CoE Consultant Manual*. There are two stages of review for Solar Photovoltaic projects:

Staging Plan - This submission package (*refer to SCHEDULE 1 – Pre-Mobilization Checklist*) is to include at a minimum the following:

- **Mobilization Area** – a context drawing showing location on site where site trailer (if applicable) will be located, and equipment will be stored until it is staged on the building/site.
- **Fencing** – include any temporary fencing that will be installed to prevent unauthorized access to the site.
- **Roof Plan –** a drawing showing staging locations on the roof (or adjacent area) for equipment, total loading permitted (based on review and approval by a structural engineer), maximum number of pallets of modules in a given location and any site specific verification that may be required (i.e. identifying support beams, or columns to center loads on). Also indicate allowable walkways where workers are permitted to access.
- **Protection** – indicate any surfaces that will be protected (at grade, on the roof etc.) and what means of protection will be provided.
- **Parking** – provide an indication of parking for contractors (either offsite or onsite) and location.

Shop Drawing Submittals – A shop drawing shall be submitted to comply with section *01330 – 1.3 (Shop Drawings) listed in Design and Construction Standards – Volume 1 General* for all major equipment, even if that equipment is base bid in the design documents. All optional features shall be circled, and electronic copies of the shop drawings shall be made available to the Owner and Engineering consultant to review:

- **Modules** – provide a datasheet, and installation manual for the specific module being supplied. Ensure that the installation manual includes specific clamping zones and permitted bonding methods.
- **Racking** – provide a datasheet and installation manual. Ensure the installation manual or supporting documentation includes the torque value (or range) that is require for each mechanical connection. Also provide proof of UL-2703 compliance for the specific module being used with this racking. Racking systems require Canadian certification for bonding (CSA-C22.2 No. 41) and must also meet the requirements of Alberta STANDATA 18-CECI-64. Ensure the racking shop drawing is stamped by the Engineer-of-Record for the racking, and suitable for submission to the Authorities Having Jurisdiction.
- **Inverter –** provide a datasheet and installation manual for the specific inverter being supplied to the project. Ensure the manual includes mounting and spacing requirements, as well as the necessary electrical and mechanical connection details. Include datasheets for any inverter coupled optimizers or shut-off devices.
- **Optimizers (e.g. MLPE) –** provide a datasheet for the optimizers indicating make model. Also include an installation and operations manual that details proper handling and servicing requirements.
- **Rapid Shutdown Equipment (if applicable) –** provide a datasheet on the rapid shutdown equipment (e.g. DC contactors, switches, initiators etc.).
- **AC/DC Conductors & Supporting Devices –** provide datasheets and catalog cutsheets for AC and DC conductors and Bonding systems (e.g. WEEB or equivalent). Including all devices proposed to support the conductors (e.g. zip ties, wiring clips, cable tray, roof blocks etc.)
- **Disconnects, Switches & OCPD** – provide datasheets or catalog cutsheets indicating the type, size, rating, and enclosure specification for all disconnect switches and other overcurrent protection devices (OCPD). Ensure that panelboard shop drawings include specific details on breaker trip limits, fault current ratings (kAIC) and that they are suitable for reverse power flow.

- **Combiner Panels** – provide a shop drawing of the AC and/or DC combiner panel indicating the electrical specifications, mechanical mounting and space requirements, along with electrical specifications of the breakers being supplied.
- **Transformer (if applicable)** – provide a shop drawing for the transformer including electrical specifications, mechanical mounting and space requirements, and an operational efficiency curve. Where available provide the anticipated impedance (actual impedance is typically factory tested and stamped on the, transformer).
- **Monitoring System –** a shop drawing outlining the monitoring system, components, interconnection, and wiring details necessary for a complete and functional system.

O&M Manuals – This submission package (*refer to SCHEDULE 4 – Operation & Maintenance Manual - Submission Checklist*) is to include

- Contact information for the Solar PV Contractor (e.g. address, phone number, email address)
- Photovoltaic racking sealed shop drawings.
- Product data sheets, manuals & approved shop drawings
- Product serial numbers
- Fuse/Breaker schedule
- Test Results
- As-Built documents
- Installation verification checklists
- Commissioning Report
- Instructions for semi-annual and annual maintenance required for an IEEE 1547 compliant installation.
- Documentation that all necessary approvals, permits, and inspections from the Authorities Having Jurisdiction have been obtained.
- Documentation of permission from the Wires Service Provider to energize the system.

Warranty Documentation – the contractor is responsible for registering all applicable warranties with the manufacturers on behalf of the City of Edmonton. All warranty certificates are to bear the CoE name and be provided as part of the close-out documentation. The date of warranty start shall coincide with substantial completion and/or initial energization of the system (whichever is later).

3.6.2 Tenant Review (if applicable)

Where the facility “Tenure” is currently not listed as “City Owned” an additional approval will be required by the current building owner/operator or tenant. The focus of this review will be on the logistics of the staging plan and ensuring adequate access is afforded to the tenant during construction.

3.6.3 Recording of Existing Conditions

The contractor is responsible for documenting (ideally with photographs) the pre-existing conditions of all surfaces they will be working on or adjacent to. Pre-existing concerns or issues should be reviewed with the CoE staff and documented (e.g. pre-existing damage to roofing, façade or base building equipment etc.). This similar process shall be completed after the construction work is complete to record the as-built conditions.

3.6.4 Issued for Construction (IFC)

The contractor shall request from the design team a full-sized hardcopy of the Issued for Construction Drawings. These drawings are to be maintained onsite for the duration of construction with all site-specific modifications or variations noted as the work progresses. This shall include (but may not be limited to) site specific stringing,

trenching locations, equipment placement etc. This package of drawings (known as the "redlined") shall be provided at the end of construction to the Engineer-of-Record for their review and approval. Any variations from the contract documents shall be approved in writing prior to making revisions onsite. Please refer to Section 7.8 of the *Design & Construction Standards (Volume 1 – General)*.

3.6.5 As-Built Drawings

The red-lined drawings in addition to onsite review and documentation shall be used create the As-Built drawings which shall be stamped by the Engineer-of-Record to form the "As Recorded". Where information is not directly visible (e.g. trench configuration, etc.) the as-built drawings shall be augmented by record photographs.

3.6.6 AUC Rule 007 Participant Involvement Program (PIP)

Where applicable, solar contractor must review findings of Participant Involvement Program (PIP) and ensure construction activity adheres to any agreed upon requirements such as work hours, vehicle traffic, noise levels, etc. In cases where design changes impact the aesthetics of array and/or do not fit within the existing PIP, additional notification or consultation may be required. Review the City of Edmonton Solar Photovoltaic Program – Volume 2: Design Guideline and AUC Rule 007 for further guidelines on PIP requirements.

3.6.7 Environmental

In cases where an environmental study has been completed and/or an Alberta Environment and Parks (AEP) Referral Report is available, the solar contractor must review requirements for the construction phase of the project and ensure compliance including, for example, setbacks from identified wildlife nests/dens, restricted construction periods, etc. In cases where the environmental study or AEP Referral Report requires ongoing wildlife surveys during the construction period, the solar contractor shall provide site access, site safety training and assistance to the wildlife biologists to complete their surveys

4 Pre-Construction Documentation

4.1 Notification & Approvals

As noted in section 3.6, all notices and approvals shall be formally submitted and approved by the City of Edmonton, or the Authorities Having Jurisdiction including (but possibly not limited to):

4.1.1 Site Plan Approval

For ground mounted, or carport systems where additional foundations or structures will be added to the site the standard process for Site Plan Approval (SPA) must be followed for the solar related elements. Where urban design implications require additional City Approval, (see *City of Edmonton Solar Photovoltaic Program – Volume 2: Design Guideline for details*) the Contractor shall work to provide the design team with as much detail as possible on actual equipment (e.g. module make/type).

4.1.2 Wires Service Provider (WSP) Pre-application Review

Contractor or consultant shall notify EPCOR of proposed grid-connected system location and size to solicit feedback on distribution feeder capacity and to confirm requirements for SCADA/control requirements. Note that confirmation of capacity from EPCOR during the pre-application review stage does not secure grid capacity – EPCOR will only approve the interconnection after the EPCOR Microgen Form A (Micro-Generation Application) has been submitted and approved.

4.1.3 Alberta Roofing Contractors Association (ARCA) Warranty Certificate

If a pre-existing ARCA Warranty Certificate is associated with an existing roof, written approval from the ARCA should be documented prior to commencing PV array installation. Early involvement of the ARCA is preferred, as the written approval should be obtained during the Design Stage.

4.1.4 Development Permit

Projects will require a development permit from the City of Edmonton prior to starting any work on site. Applications will require supporting documentation including site plans, elevations, etc. showing bylaw compliance. Typical processing time is 3-6 weeks for complete applications.

4.1.5 Building Permit

All projects shall be required to secure a building permit with the City of Edmonton prior to completing any work on site. Building permit applications will not be processed by the City of Edmonton until a Development Permit has been approved and issued. Typical building permit processing time for complete applications is 3-6 weeks depending on city permit office volumes. It is the responsibility of the contractor retained to construct the system to ensure that all shop drawings (e.g. racking, foundations etc.) that are submitted are accurate and complete. The contractor shall work with the City of Edmonton Building Department to schedule required inspections.

4.1.6 Electrical Permit

An electrical wiring permit must be applied for and received form the Authorities Having Jurisdiction at the City of Edmonton prior to any work commencing onsite. This permit is also required prior to making a connection application to the Wires Service Provider (e.g. EPCOR). The City of Edmonton will not issue an electrical permit until the building permit is issued for the project. Application will require electrical single line diagrams and major component data sheets. If rapid shutdown is required, a site plan indicating the location of the initiating devices will be required.

4.1.7 Wires Service Provider (WSP) Application

The Wires Service Provider (e.g. EPCOR) requires an electrical permit to be received from the City of Edmonton prior to reviewing connection a Micro-Generation Applications. In line with this application the contractor shall confirm via the shop drawing process the specific make and model of inverter that will be procured for the project and any supervisory, monitoring and control (SCADA) equipment. The EPCOR Micro-Generation Application requirements are discussed in more detail within the City of Edmonton *Solar Photovoltaic Program – Volume 2: Design Guideline*.

4.2 Pre-Mobilization Approvals

In addition to the permits for the Authorities Having Jurisdiction, and prior to mobilization onsite it is the responsibility of the contractor to have provided to the City of Edmonton (and received review comments on documents) for:

- **Safety Documentation** – both site specific and the contractors (and their sub-contractors) safety policies and programs in accordance with municipal and provincial Occupational Health & Safety requirements.
- **Staging Plan** – provide a site-specific staging plan, as defined in section 3.6.1, for review and comment by City of Edmonton (and Tenant where applicable).
- **Site / Roof Access Plan** – provide confirmation of compliance with the design team intended site/roof access plan or provide an alternative plan for review and comment by the City of Edmonton.

Depending on the type of site and nature of the installation onsite – the City of Edmonton, at their discretion, may require additional documentation or planning to be in place prior to mobilization.

4.3 Meetings & Site Reviews

Site specific requirements will be identified for all parties prior to scheduling pre-mobilization meetings and/or site visits. These may include, but are not limited to site specific sign-in or orientation requirements, PPE requirements, site access forms, etc.

4.3.1 Pre-Construction Inspection

Prior to mobilization onsite, and following the award of the project, a review shall be conducted onsite jointly with the contractors designated site supervisor, the consultant (e.g. Engineer-of-Record) and the City of Edmonton staff overseeing the project or facility to review and document any existing conditions. Specific attention should be made to anything in the general area of construction which indicates pre-existing damage, or which may require relocation or replacement in conjunction with the solar photovoltaic project construction.

4.3.2 Construction Meeting(s)

Where specified, mandatory site meetings will be required for all parties involved with the installation of the system. These may be specified once prior to mobilization, or on regular (e.g. weekly) intervals. These meetings may commence prior to mobilization depending on the site-specific requirements for access and complexity of the coordination with the City of Edmonton, tenants, or building occupants.

4.3.3 Site Reviews

During construction, the contractor is to make qualified staff available to assist in the review of the site by the engineers, consultants or City of Edmonton staff involved in the project. For clarity, this may involve isolating portions of the system, opening equipment or otherwise reviewing the construction project. Efforts will be made by those seeing access to the site to provide advanced notice, and an indication of purpose and intent of the visit. Please refer to the Section 7 - Commissioning Requirements for specific requirements at that stage.

4.4 Shop Drawing Review

As noted in section 3.6.1, all applicable shop drawings must be submitted to and reviewed by the Consultant (e.g. Engineer-of-Record), the City of Edmonton (or tenant depending on scope) and returned to the contractor prior to procuring or storing equipment on site.

4.5 Issued for Construction Drawings

Once shop drawings have been submitted and reviewed as noted (without any further requested revisions) the Engineer-of-Record shall prepare the final Issued for Construction (IFC) drawings which will provide site specific and equipment specific details. Typically, this document cannot be created until the final racking layout and associated shop drawing has been completed. This final set of drawings should be the definitive reference for equipment location, DC string configuration (and numbering) used for the installation of the system.

4.6 Coordination

The contractor shall be responsible for procuring and coordinating all locates for all activities onsite. The contractor shall review the drawings and specifications and where questions exist, shall request additional information and/or clarification about the design from the Consultant (e.g. Engineer-of-Record) as needed to expedite the work.

The contractor shall ensure that appropriate supervision by their staff is in place when work is taking place onsite regardless of if the work is provided by the contractor, their designated sub-contractor, or another entity. The photovoltaic system and its constituent parts remains the responsibility of the contractor from initial mobilization to owner hand-over at the completion of construction.

4.7 Field Supervision

A designated contractor supervisor shall supervise contractor personnel (including sub-contractors, as applicable). The supervisor shall be on site at all times when work is being performed by the Contractor and/or sub-contractors. The supervisor shall not be changed without prior notice provided to Owner in advance of any transition in staffing.

This means it is the contractor's responsibility to ensure all staff working in and around the solar photovoltaic system are qualified or supervised by qualified workers (e.g. where work may be un-related to the electrical aspects of the system). The Contractor Supervisor shall advise all Contractor personnel (and any other individuals working in close proximity to the PV system) that PV modules generate dangerous electrical charges when exposed to sunlight and are always "ON" whenever they are exposed to sunlight. Throughout installation, source string circuits shall be properly secured, covered, and/or terminated when left unattended by Contractor personnel to minimize exposure risk in accordance with CSA Z462.

4.8 Preparation & Staging

Signage onsite shall be posted in accordance with the Site Staging plan, including but not limited to: warning signage and/or way-finding signage for vehicular or pedestrian traffic. A site office shall be established and equipped with all necessary project documentation including safety compliance, construction drawings. Fencing and access control provisions (as may be required) shall be installed and operational prior to any equipment or materials being delivered to site.

All means of temporary & permanent construction access to the site or roof shall in compliance with Part 9 of OH&S and be reviewed and approved by an engineer licensed to practice in the Province of Alberta. Stair towers, vertical access, or staging platforms shall be installed, reviewed and verified by the Engineer prior to use for construction activities.

4.9 Delivery, Storage, and Handling of Products

All equipment must be in new condition, and packaging free of dust, moisture, and physical damage. Any equipment not satisfying these requirements will be rejected at the City of Edmonton's discretion. All equipment once onsite must be stored in secure, rigid, dry, weather tight locations free from damage by dust, moisture or physical abrasion. Equipment stored onsite during construction is the responsibility of the Contractor. Where practicable, all materials used to ship (e.g., spools, pallets, tarps etc.) materials and products shall be reused and recycled at the end of their useful life.

4.10 Rooftop Staging & Storage

Where required by the project implementation approach, the contractor shall review and amend or provide a rooftop staging plan that indicates location and loading capacity of roof areas that will be used to stage, or store materials. All materials and equipment staged on the roof shall be positioned in accordance with this plan and with the necessary temporary roofing protection as specified within section 6.1 of this guideline. Variations from the staging plan shall be submitted for review and comment prior to making amendments.

4.11 Building Operations

Most of the host facilities that will be receiving solar photovoltaic systems will be in operation, and as such the contractor is expected to work collaboratively with facilities maintenance staff, and building operators to minimize the impacts of construction on the occupants and operations of the facility. For facilities receiving a major renovation, expansion, or renewal – a similar expectation exists for the contractor's interaction with other trades operating in and around the site.

Furthermore, the expectation is that where potential interferences exist, or hindrances may be created to the smooth and orderly operation of the facility as a result of the photovoltaic system construction, the contractor shall endeavor

to alert the City of Edmonton staff involved with the project, and corresponding facilities maintenance staff of these concerns so that they can be resolved in a timely manner.

5 Execution

5.1 Contract Administration

All contractual documentation (e.g. SI, CCN, etc.) shall be prepared and submitted in accordance with section 2.3.4 of the Consultant Manual (Vol1 Design Process & Guidelines– v4.0). No remuneration for changes from the Issued for Construction drawings will be approved without the appropriate documentation.

5.2 Monitoring & Reporting During Construction

Weekly progress reports must be submitted to the City of Edmonton project manager with work completed and photo documentation. Reports shall indicate percentage completion on major components (e.g. racking, module installation, array wiring, inverter installation, AC/DC wiring and AC balance of systems). Issues identified during the prior work period, and any safety concerns or issues that arose shall also be included in the report.

Weekly progress meetings must also be held in accordance with *section 01310 – 1.3 (Progress Meetings) listed in Design and Construction Standards – Volume 1 General.*

5.3 Cutting and Patching

All cutting and patching of the existing facility shall be in accordance with the City of Edmonton construction requirements, and the *CoE Solar Photovoltaic Program Volume 2 Design Guideline* in relation to penetrations, firestop sealing and maintenance of thermal, air, and water barriers within the structure. The finished surface shall be painted or covered to match the surrounding substrate.

5.4 Cleaning

The contractor shall remove all excess compounds, adhesives, sealants, filings, tape residue, dust, and other debris from all PV system products once installation is complete. The contractor shall remove all packaging, off-cuts, and other miscellaneous debris from the work area and reuse, recycle, or dispose of the waste in accordance with the City of Edmonton requirements (e.g. recycling policies).

Module cleaning should only be undertaken using non-pressurized water sources (e.g. to avoid unwanted water penetration into the frame edge) and using a mild soap approved for use by the module manufacturer. All modules shall be cleaned prior to Instantaneous Yield Test (Refer to PROTOCOL 7) and prior to hand-over of the system to the City of Edmonton operations group.

5.5 Aesthetics of Installation

All products shall be installed to provide a clean and aesthetically pleasing appearance using non-oxidizing/corroding materials. Routing of conduit must not interfere with the working space of existing equipment. All areas disturbed during construction shall be remediated, re-graded and/or re-seeded to match original condition.

5.6 Snow Removal Work Procedure

Extreme caution should be taken in working in and around solar photovoltaic modules during winter conditions. The risk of microfractures caused by physical contact with the modules is increased significantly with sub-zero temperatures. Clearing of snow should be undertaken only with soft bristle brooms or brushes, or with non-contact blowers (e.g. leaf blower). Shovels, scrapers, or other abrasive means of removing snow shall never be used for removing snow directly from modules.

Figure 2 - PV Array (Winter Conditions)

5.7 Electrical Clearances

The minimum electrical requirements are clearly defined in the Canadian Electrical Code (CEC) and are not be deviated from unless written approval from the City of Edmonton Safety Codes, Permits & Inspections (SCPI).
The electrical maintenance clearances shall be established in accordance with the CSA Z462 standards. Please refer to *Table 5 – Limited Approach Boundary* in the *CoE Solar Photovoltaic Program Volume 2: Design Guideline* for voltage references.

Contractors performing work within these limited approach boundaries must be qualified and have the appropriate training as to the risks and hazards of solar photovoltaic systems and DC power.

5.8 Torque Validation, Verification & Quality Assurance

All fasteners (electrical and structural) are to be tightened to the appropriate torque levels as specified by manufacturer literature. A comprehensive torque verification program shall be implemented by the contractor, including calibration of drivers, wrenches and electronic tools. These calibration certificates shall be maintained onsite, and where practicable validated on a weekly basis (i.e. working tools are tested against reference quality assurance tools).

Verification of the torque program shall be undertaken at the discretion of the City of Edmonton or their consultant. Where connections are tested by the project staff or their designated consultants, a RED torque paint or marking shall be applied to indicate which connections have been verified. Where >5% of the tested connections fail, the contractor will be responsible for returning and completing re-torqueing on the impacted system locations and connections.

Figure 3 - Uninsulated Dial Torque Verification Wrenches

5.8.1 Mechanical Connections

The contractor shall ensure that **100%** of mechanical connections are torqued in accordance with the racking manufacturer requirements. Electric drills and drivers that have torque settings are not to be relied on solely for ensuring this is accomplished - due to the variance in torque that can occur (based on state of charge, and impact factors). Instead a ratcheting manual torque driver shall be used to ensure consistent levels of torque are achieved. All connections are to be marked (using a **BLACK** torque paint or marking) that extends across the head of the fastener and onto the surrounding substrate (e.g. clamp, bracket, or structural member).

A torque validation program shall be instated by the contractor supervisory staff to test **10%** of all mechanical connections within the system. This includes racking connections, module-to-racking connections, and other related structural connections (e.g. for ground mount pile caps, east-west beams, north-south members etc.). These connections shall be tested with a calibrated torque driver or dial torque indicator, and tested connections shall be marked with **YELLOW** torque paint or marking).

5.8.2 Electrical Connections

The contractor shall ensure that **100%** of electrical connections are torqued in accordance with the electrical equipment manufacturer requirements. Where torque values are not specifically provided by the manufacturer – the values included in the Canadian Electrical Code shall be used instead.

A torque validation program shall be instated by the contractor supervisory staff to test **100%** of connections for conductors 8 AWG or larger. These connections shall be marked with a **RED** torque paint that extends between the lug or set screw and the terminal it is housed within. Paint shall be used instead of marker so that if shifting occurs in the terminal it will show as a visible crack in the torque marking.

For conductors 10 AWG or smaller, the contractor supervisory staff shall test **50%** of all connections. This includes testing for DC, AC and low-voltage wiring. These connections shall be tested with a calibrated torque driver or dial torque indicator, and tested connections shall be marked with **YELLOW** torque paint or marking. For setscrew terminals where a marking cannot be applied directly to the screw, a dot of paint on the housing is acceptable to indicate that the termination was properly torqued.

5.9 Specialized Tools

5.9.1 Quick Connect Crimper Kit

All single conductor cable terminations shall be made using an UL 6703 approved connector (e.g. Multi-Contact MC4, EVO2, or Amphenol H4) and approved termination kit for the specific connector being used. All components of the kit shall be used, including slingshot wire strippers (to prevent damage to copper conductors), approved crimping kit for appropriate pressure and securement, and the torque driver and associated socket for properly

securing strain relief grommets. Connectors rated for both the conductor size, and jacket size shall be sourced to prevent ingress of water into the connection.

Staubli M4-Evo Assembly Kit

Amphenol H4 Assembly Kit

CSI T4 Assembly Kit

Figure 4 – Quick Connect Assembly Tool Kit

It should be noted that the crimping tool, dies, and associated connectors are not interchangeable, and so the kit designed and CSA certified for making the specific connections must be used every time a field termination is made.

5.9.2 Insulated Torque Screwdriver

It is good practice to utilize an insulated torque screwdriver for making all mechanical and electrical connections within an inverter, combiner box or rapid shutdown device. This minimizes the risk of static discharge and minimizes the risk of inadvertent shock. All insulated torque screwdrivers shall comply with CAN/ULC 60900-99 and be rated for the maximum possible voltage of the device for which it is being used on (e.g. 1000VDC).

Wiha Insulated Driver

Wera Insulated Driver

Figure 5 – Insulated Torque Screwdrivers (examples)

6 Installation

The construction approach shall be executed at the discretion of the contractor, however there are a number of requirements that shall be addressed with the installation of the system including:

6.1 Roof Protection

The contractor shall take every step possible to protect the roof surface. This means ensuring a comprehensive training program for staff on the responsibility to prevent punctures or damage, and where such damage occurs to report and remediate it in a timely manner. Excess tools not required for a specific job should be staged at grade, and not brought to the roof surface to minimize the risk of damage to the roof. Insulated modified bitumen and built-

up roofing (BUR) roof assemblies should be adequately protected with **13mm** (1/2”) plywood or **11mm** (7/16”) oriented strand board (OSB) sheathing. An additional layer of **25mm** (1”) extruded polystyrene insulation (XPS) should also be installed for all other conventionally insulated roof membrane types.

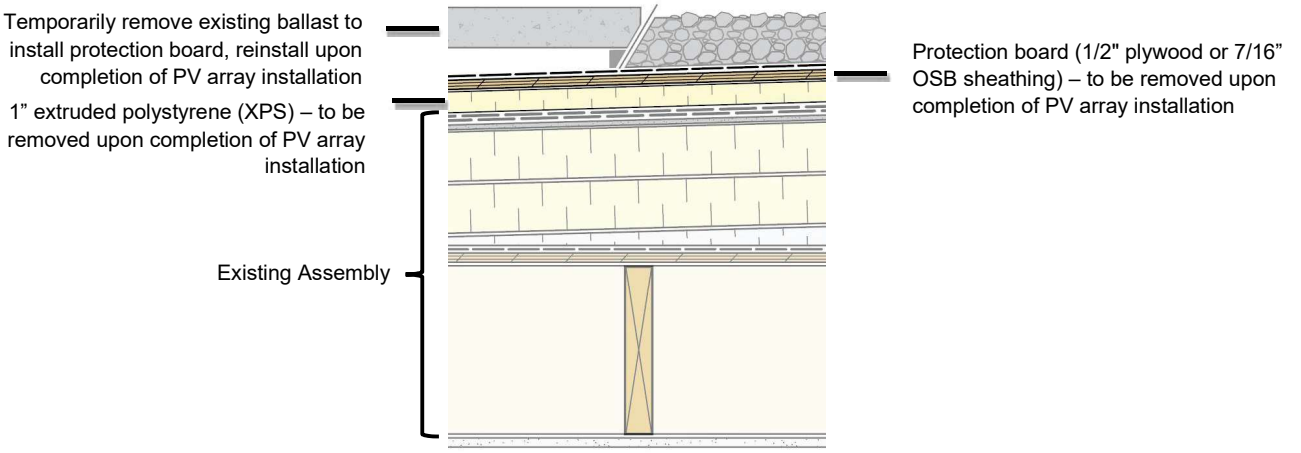


Figure 6 – PV Array & Equipment Protection - Built-up Roof (BUR) Assembly

For inverted systems where the existing insulation is protected with ballast, the ballast should be temporarily removed and have **13mm** (1/2”) plywood or **11mm** (7/16”) oriented strand board (OSB) sheathing installed. Prior to relocating the ballast, the structural capacity of the roof deck should be reviewed so that overloading does not occur.

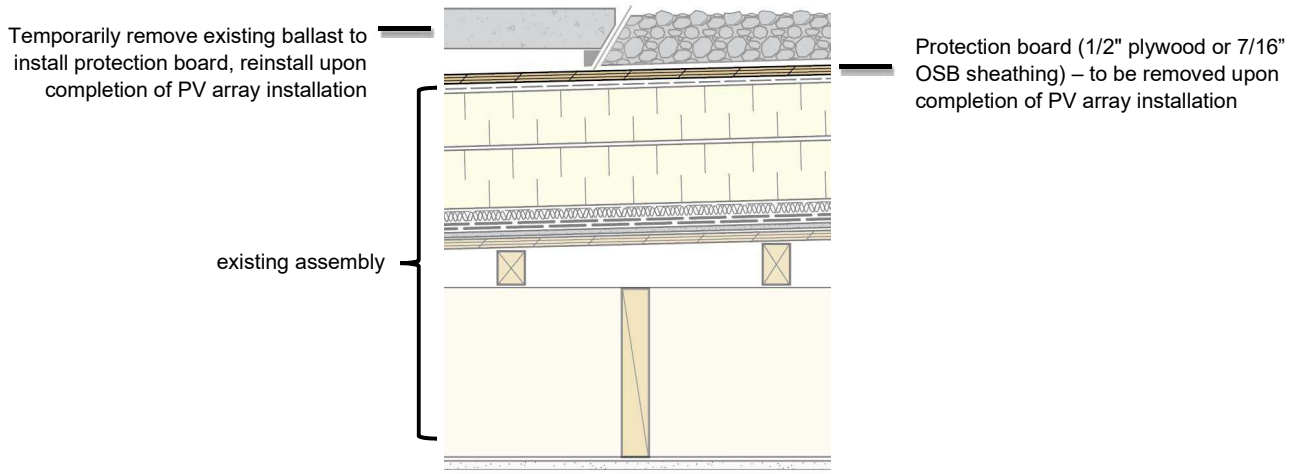


Figure 7 - PV Array & Equipment Protection – Inverted Roof Assembly

Protection areas should extend a minimum of **1000mm** (3.3’) past the point of anticipated area to accommodate falling components and imprecise placement of materials and components.

All designated walkways to be used by PV array installers should be protected by two rows of 4’x8’ sheets of **13mm** (1/2”) plywood or **11mm** (7/16”) OSB sheathing over **25mm** (1”) thick XPS, creating an 8’ wide pathway. All foot traffic should not deviate from designated walkways, especially with single-ply membrane roofs. If deviating foot traffic is anticipated the same roof protection noted above should be implemented.

6.1.1 Roof Preparation

The roof membrane shall always be protected. The specific way to do this will vary somewhat depending on the roofing system. However, the approach shall always be to remove ballast, debris, or other obstructions from the roof first. Then Type 4 XPS shall be placed directly on the roof surface, with **19mm (3/4")** plywood installed directly on top. The equipment pallets and associated materials can then be landed on that surface. Attention shall be paid to ensure the total weight at a given location does not exceed the staging plan approved prior to construction.

6.1.2 Roof Securement

All materials and equipment stored on the roof shall be covered, and secured with appropriate straps, ballast or other means to ensure that none of it is blown around or off the roof. These measures shall be in place during hours of active construction or after hours and detailed within the contractor's site-specific safety plan.

6.1.3 Monitoring

The construction supervisor shall maintain an active review of activities on the roof to ensure that the roof membrane is not being compromised. This will include a pre-assessment of the roof membrane to coincide with (at minimum) a weekly review documenting with photos demonstrating compliance with the roof protection requirements.

6.1.4 Roof Testing

After installation of the PV array system is complete if there are concerns about the integrity of the roof membrane it may be required to conduct infra-red (IR) imaging to identify and help isolate locations of damaged roof membrane. Depending on the time of year, and if the roof assembly is a conventionally insulated modified bitumen or built-up roof (BUR) membrane roof, the roof may be flooded for a period of 24 to 48 hours then drained. An IR scan may identify locations where water has penetrated the roof and the appropriate repairs can be implemented. The City of Edmonton life cycle and facilities departments should be involved with any determination regarding if this testing is required. If water ingress into a roof assembly is confirmed, the damaged area and affected insulation will also have to be replaced (except in inverted assemblies).

It should be noted that IR scans are typically not effective for ballasted, inverted, and most single-ply systems. If an IR scan detects water has penetrated a roof assembly, the damaged area and affected insulation will also have to be replaced (except in inverted assemblies where the insulation will not have to be replaced).

When IR scans are warranted by the City of Edmonton, the Contractor shall retain the services of a Certified Thermographer (LEVEL 1 or higher) who shall carry out infrared thermal scans and analyze the resulting images.

6.2 Racking System

6.2.1 Storage

All parts of the racking system shall be stored such that they are free from moisture accumulation. Racking members shall be properly supported along their length to prevent deflection or deformation prior to installation. All parts shall be inventoried upon arrival and fasteners verified for correct material type (e.g. stainless steel) and quantity.

6.2.2 Handling

Racking shall be lifted to the roof or distributed around the site using a properly secured lifting means. Alberta Occupational Health & Safety requirements shall be strictly adhered to for the lifting of any and all materials. It is important for oversized lengths of racking that a level and obstruction free landing zone is prepared prior to lifting.

6.2.3 Installation

Racking shall be installed in accordance with the latest revision of the manufacturers racking installation manual. All fasteners shall be installed finger tight until the overall assembly has been erected and is squared. The inter-racking connections shall be tightened to the appropriate torque value (and marked in accordance with section 5.8.1). Only once that is complete and the racking is close to square shall modules be installed.

6.3 Photovoltaic Modules

6.3.1 Storage

All PV modules should be stored in such a matter as to prevent wetting of the module packaging (e.g. typically that is cardboard) and to prevent accumulation of liquid water on the back side of the frame. Modules staged onsite shall be positioned face up so that water cannot accumulate inside the frame. Module whips shall be protected at all stages of construction from both liquid water, and prolonged exposure to humid conditions.

6.3.2 Handling

Large format modules (e.g. 72 cell modules) shall always be handled by two workers. The risk of damage due to deflection or deformation of the module substrate is significantly increased when being handled by a solo worker. Modules should never be dragged across adjacent modules (either modules already installed or those still on the pallet). The manufacturer's installation manual should be referenced for product specific handling and installation instructions.

6.3.3 Installation

Modules shall be installed in accordance with the racking installation manual. Clamps shall be installed within the "solid hatch zone" or approved point of connection on the modules. Where questions or concerns exist about the location of appropriate clamping or connection points – these should be submitted in writing to the manufacturer for clarification.

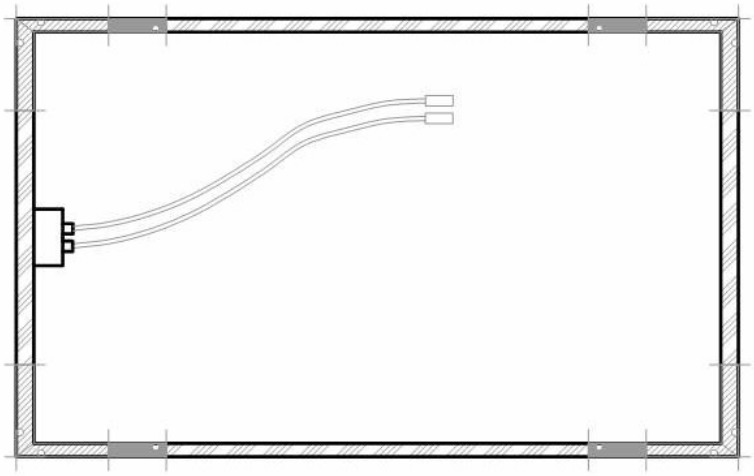


Figure 8 - Module Clamping Zones

The specific approvals are module and model specific – so it is always advisable to ensure that the latest version of the installation manual is consulted before installing. Any variance from the documented positioning or locations requires written approval from the manufacturer. For this documentation to be acceptable, it should include a letter referencing the product, and serial number series (specific to the site), giving explicit approval for the variation and stating that the warranty will be fully in effect.

6.3.4 Interconnection

Figure 9 - Module Connectors

Qualified workers with appropriate PPE shall conduct a moderate pull test on ALL leads to ensure a proper connection is made within the junction box, and between the connector and the lead. All leads shall be prevented from contacting the roof surface during installation, particularly where excess moisture or dust is present. Module leads shall be capped with compatible MC4 (or equivalent) connector caps where individual leads, or string leads are left unconnected. These caps shall remain in place until modules are fully terminated. Bonding of the modules shall be installed at the same time as the modules are installed with a solid ground reference throughout the installation (even prior to interconnection with the inverter). This minimizes the shock hazard related to possibly damaged equipment (i.e. prior to being verified through the commissioning process).

To avoid having additional setbacks applied to the array, the module orientation and string design should take into consideration maintaining those distances from quick connects, and home run terminations where practicable within the array. This can be done by specifying the orientation of modules (such that the junction box and whips are internal to the array). Please refer to *Figure 1 – Wire Management within Limited Approach Boundary* in the *CoE Solar Photovoltaic Program Volume 2: Design Guideline* for further details.

6.3.5 Labeling

Where Module Level Power Electronics (MLPE) (e.g. DC optimizers, or micro-inverters) are used, the contractor shall maintain an as-built record that accurately documents position of module and optimizer/inverter pair within the array and reference ID for that equipment.

6.3.6 Warranty

The contractor shall ensure they locate and include within the O&M manual the product specific warranty for the modules delivered to site. The installation manual corresponding to this product shall also be included for reference purposes. The contractor shall request the Flash Test Data from the manufacturer in digital format (e.g. *.xls or *.csv). Ensure that the provided flash test corresponds to the serial numbers of the modules installed onsite.

6.4 Array Wiring

Array wiring relates to any wiring within the solar PV array and not extending greater than **1 m** from the array. For string or central inverters this wiring is typically DC. For microinverters this wiring is AC wiring (although some DC exists between the module and the microinverter).

Figure 10 – Covered Array Wiring (e.g. Liquid Tight, Metallic covers, or split loom)

6.4.1 Storage

All wiring shall be stored in a clean dry location. Where ends are exposed these should be removed prior to termination to avoid potential issues associated with oxidization of the exposed conductor. For prefabricated wiring harnesses or bus cables, all connection points and terminals shall be securely capped, and caps shall only be removed immediately prior to making the connections.

6.4.2 Handling

Attention should be paid during the installation of the wiring to ensure that the outer jacket is not damaged during the staging and installation of the wiring. This is particularly the case where sections of the racking system, or wireway are not properly installed, or protected.

6.4.3 Installation

All wiring shall be installed in accordance with the racking manufacturers requirements. Wiring that is exposed in lengths sections **50 mm (2")** or longer shall have a UV resistant split loom or other means to provide UV protection in addition to the standard UV rated wire jacket. Where conductors exit a junction box, they shall be secured to the nearest structural member (module frame or racking) along the most direct path between modules.

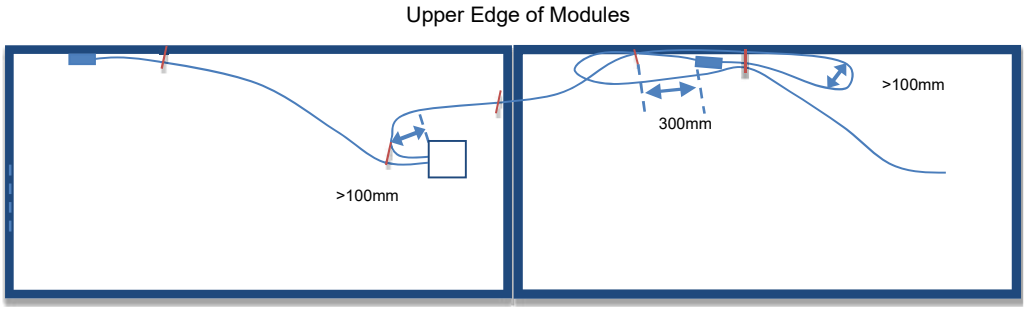


Figure 11 – Wire Management Considerations

All cables shall be secured with nonmetallic PVDF zip ties with metal pawls (suitable for UV exposure, chemical and moisture resistance, and rated for 50 lbs of loading) shall be used throughout the system. Ensure all conductors are supported in accordance with the CEC – including within **300 mm (12")** of all connections (e.g. junction box and connectors) and every **1000 mm (3.3 ft)** along straight runs.

6.4.4 Termination

Quick connects (MC4, EVO2, H4 or equivalent connector listed by module manufacturer as compatible with module connectors) shall be installed on all strings and capped with an approved quick connect cap. String to "homerun" connections shall NOT be made to module strings until the uncontrolled end (e.g. that runs to the inverter, or combiner box) has been fully terminated and secured. Once the home run has been secured at the inverter an insulation resistance test (IRT) shall be completed for the run prior to interconnection with the string.

6.4.5 Labeling

Homerun string wiring, (and AC trunk cables) shall all be labeled consistently on either end in accordance with the construction drawings. These labels shall include the Inverter, and String numbers (or for microinverters branch labeling) using a UV resistant shrink-wrap. On ballasted systems, a colour coded lamacoid string tag shall be installed (e.g. zip tied to the racking) at the location of all string (+) and (-) connections on the outside of the racking to facilitate easily identification and isolation when required. On flush mounted systems, an accurate string diagram and roof plan shall be maintained showing the location of connectors required for isolation.

6.5 Inverter / Combiner

Clearances around installed electrical devices shall meet all Canadian Electrical Safety Code & Wires Service Provider requirements and shall allow for easy access for operation, maintenance, and repair. Devices shall be oriented and installed such that access doors are conveniently located and not blocked by existing equipment or access control provisions (e.g. fencing, or enclosures). Mounting heights of installed products shall be readily accessible for easy access for operation, maintenance, and repair. All component switches are to be in the OFF or OPEN position and all fuses removed prior to installation. They shall remain in this position, locked-out by contractor, until system commissioning tests can be completed.

6.5.1 Storage

Inverters (and/or combiners) shall always be stored in a dry secure location. Any moisture ingress into packaging can compromise the integrity of the equipment. The contractor shall inspect all packaging upon arrival and document (with photographs) that it is intact, and no physical damage exists.

6.5.2 Handling

Inverters (and/or combiners) shall always be lifted, stored, and handled in accordance with the manufacturer's requirements. Ensure the installation manual being referenced is the most recent for the equipment provided. Where possible, coincide equipment lifting with mechanical installation so that the inverters are not exposed to inclement weather except in the position where they are intended to operate.

6.5.3 Protection

Ensure that equipment covers, access panels, and shields are always installed and securely fastened. If the equipment will be exposed to winter conditions while in a de-energized state – review with the manufacturer to determine if any additional protection or heating will be required for the duration of construction.

6.5.4 Installation

Ensure that the installation method called for in the construction documents are in accordance with the manufacturers most recent installation manual. Where discrepancies exist, provide these in writing to the Engineer-of-Record for resolution and direction. Attention should be paid to the placement of equipment to ensure that it is not exposed to extreme conditions such as excessive direct sunlight, snow drifting, or ice build-up due to drainage paths from upper roofs or adjacent equipment.

Figure 12 – Example Inverter Mounting Structure (prior to shade cover installation)

6.5.5 Warranty

The contractor shall ensure they locate product specific warranties for the inverters or combiners. When unpackaging the equipment the contractor shall locate and include, in digital form, any quality assurance documents such as calibration certificates, Factory Acceptance Test (FAT) reports or other warranty specific information within the O&M manuals. The contractor shall record all serial numbers and register the equipment with the manufacturer for inclusion in the equipment warranty documentation required for the O&M manual. The date of registration shall coincide with the hand-over of the system to the City of Edmonton.

6.6 AC Wiring

6.6.1 Wiring Storage

Ensure wiring is stored in clean dry locations, protected from direct UV exposure. As noted in the DC section, even UV resistant wiring is only rated for a limited exposure to direct UV.

6.6.2 Wiring Labeling

All colour coding of wires shall be in accordance with standard 3 phase or single-phase power systems. Contractors may elect to label black phase conductors with Yellow tape/shrink wrap. Where wire identification is completed with tape or shrink wrap – the coloring should be applied to at least three (3) locations along the exposed length within the device. It is recommended that labeling be applied before conductors are pulled, and then replaced if damaged during the wire pull.

6.6.3 Wiring Protection

All conductors installed in conduit (or ACWU90 / TECK90 hubs) shall be protected from abrasion with bell ends or a plastic bushing installed regardless of cable size. Ensure that cable fill ratio (even if it is in accordance with CEC) does not put undue stress on the conductor jacket specifically at the LB (or equivalent) connections.

All wiring shall be installed in conduit or cable tray to ensure that it is properly supported along its entire length and does not contact the roof surface, parapet, or wall assembly. Please refer to *CoE Solar Photovoltaic Program Volume 2 Design Guideline* for specific details on support and building assembly protection.

6.6.4 Termination

Ensure that wire insulation and jacket is removed such that the metallic conductors are not damaged or scored. For smaller size conductors utilize properly sized wire strippers (slingshot or equivalent) to prevent inadvertent damage to conductors.

Ensure that conductor sizes are compatible with the lug or assembly they are to be terminated within. Always confirm that the lug body and associated connection hardware is rated for the type and number of conductors (e.g. Cul/Al dual rated) prior to terminating the wire. Apply antioxidant paste on all connections where dissimilar metals exist as directed by the manufacturer literature for the termination. For bus bar connections (e.g. within switchgear or transformer), the contractor shall use an irreversible barrel crimp paddle style lug installed with a die and lug set rated for the conductor and crimp. Where possible use a dual fastener paddle for maximum contact with the bus assembly.

Figure 13 - Barrel Compression Lug

6.7 AC Balance of System Components

Clearances around installed electrical devices shall meet all Canadian Electrical Safety Code & Wires Service Provider requirements and shall allow for easy access for operation, maintenance, and repair. Devices shall be oriented and installed such that access doors are conveniently located and not blocked by existing equipment or access control provisions (e.g. fencing, or enclosures). Mounting heights of installed products shall allow for easy access for operation, maintenance, and repair.

All component switches are to be in the OFF or OPEN position and all fuses removed prior to installation. They shall remain in this position and locked-out by contractor, until system commissioning tests can be completed.

6.7.1 Storage

Ensure all disconnects are stored in a clean dry location. Any moisture ingress into packaging can compromise the integrity of the equipment. The contractor shall inspect all packaging upon arrival and ensure no physical damage exists.

6.7.2 Labeling

Ensure all disconnects and balance of systems equipment are labeled in accordance with the construction documents, indicating the specific electrical device (as noted on the Single Line Drawing) and with any safety or warning labels.

6.7.3 Protection

All disconnects shall be installed in the location and exposure for which they are rated. Drains or breather/drains shall be installed to ensure that any moisture ingress has a path to exit the enclosure. Disconnects or devices accessible to the general public shall be contained within a lockable enclosure or mesh/fenced. Locks shall be installed on all enclosures, or where available tamper or vandal resistant fasteners shall be used (e.g. transformers).

Figure 14 – Example Disconnect

6.7.4 Installation

All enclosures shall be installed plumb and square to ensure that doors open without resistance. All safety bypass methods shall be intact and operational. Enough space shall be provided on the sides of the device to safely access open/bypass the enclosure for IR imaging.

6.7.5 Interconnection

As noted within section 3.7.1 of the *CoE Solar Photovoltaic Program Volume 2 Design Guideline* different interconnection strategies could be required to accommodate the final connection point of the PV system.

All interconnection options will require the contractor to perform a full building electrical shutdown as part of the final connection within the main switchgear, switchboard or fused disconnect. Prior to scheduling and planning the shutdown, the contractor is to complete the “Project Readiness Document”. This document will be reviewed by the necessary City of Edmonton staff and indicate which “Building Systems Shutdown Permit” application/s need to be completed. Permits for planned shutdowns require 10 days advanced notice.

The shutdown procedure is to be conducted in accordance with CSA Z462 and detailed within a formal Electrical Shutdown Plan that is to be coordinated and approved by the City of Edmonton prior to scheduling of the final interconnection. The proposed Electrical Shutdown Plan and Procedure is to be completed in conjunction with the Facilities “Building Systems Shutdown Procedure (V3.0)” document.

The Electrical Shutdown Plan is to include strategies for, but not limited to:

- Load dropping/switching – reducing loads within the facility in a safe and responsible way.
- Backup power for Critical Loads – either back-up generator or onsite generators (if approved by FMS).
- City of Edmonton requested support (e.g. City electricians, building maintenance staff)
- Load reconnection plan – to reconnect loads and ensure proper startup of all base building equipment including (but not limited to): equipment, controls, fire alarm systems etc.

Where indicated within the design documents that further investigation of the existing service is required by the contractor prior to determining the type of connection. The contractor shall provide detailed information (e.g. photos of main conductors, electrical buss etc.) to the design team for final interconnection direction.

6.8 Monitoring System

The monitoring system shall be installed in accordance with the manufacturers recommendation. All setup parameters shall designate the City of Edmonton as the owner with full administrative privileges. Access accounts shall be setup to be visible on the City of Edmonton dashboard for the Inverter OEM specific interface. Please refer to section 5.11 of the *CoE Solar Photovoltaic Program Volume 2 Design Guideline* for specific monitoring setup requirements.

6.8.1 Instrumentation

Consider the site-specific placement of sensors. Ensure they are consistent with issued for construction drawings. However, review with the Engineer-of-Record if the indicated locations will not be representative of array conditions (i.e. reference cell is in a drifting zone from a rooftop equipment, or if the ambient temperature sensor might be exposed to early or late day sun thus affecting its readings.

Ensure all instrumentation is mounted and affixed as per the manufacturer's requirements. The reference cell shall be positioned so it is representative of the array (in terms of tilt and azimuth). This means evaluating its tilt compared to the average array tilt (in some cases with sloped roof, or tapered insulation some site-specific adjustments may be required to ensure the sensor is level and representative of the array.

7 Commissioning Requirements

The objective of the commissioning process is to review, verify, and document that the solar photovoltaic project is ready to operate in a safe, and reliable manner in accordance with good engineering practice. The commissioning process shall also be part of a quality assurance process to ensure compliance with the City of Edmonton Solar Photovoltaic Program requirements.

7.1 Commissioning Objectives

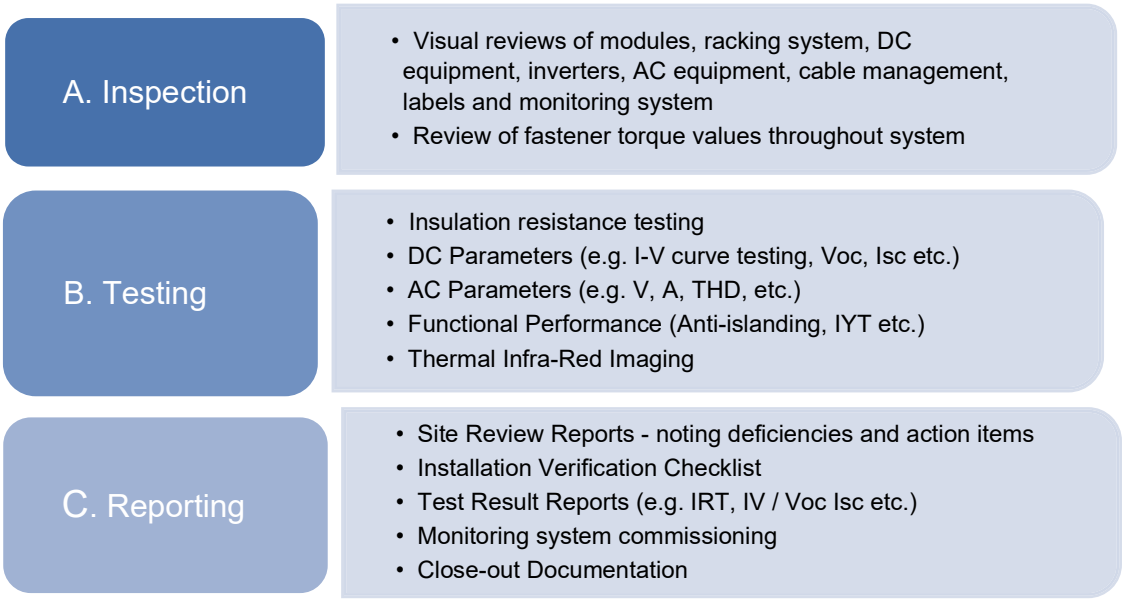
This is achieved by documenting the design intent early in the project inception phase and validating compliance with the City of Edmonton Solar Photovoltaic Program requirements through the design, construction, acceptance, and operation stages. In general, commissioning will provide a fully functional system that is:

- **Safe** – Is installed to the requirements of the contract documents and applicable codes and standards, in a way that maximizes occupant and worker safety in design, construction, and operation.
- **Durable** - Has been proven to meet all of the City of Edmonton's design and construction criteria, functional requirements, and operational requirements before the date of acceptance,
- **Reliable -** Operates consistently at peak efficiencies and with the intended performance and has been benchmarked to provide a baseline dataset to compare future test results to.
- **Maintainable -** Has complete documentation relating to all installed equipment and systems and is accessible for regular maintenance and servicing.

Commissioning is a quality assurance process that should be completed throughout all stages of the project, and not left to the end of the project when the system is ready to be energized.

7.2 Commissioning Methodology

The approach to commissioning is to minimize risk for the system, operators/workers, and the host facility. This requires a sequential process to be followed to ensure consistent and reliable results.



7.3 Winter Commissioning Protocol

On some projects it may be necessary to commission the project during the winter season, when the stated irradiance values (e.g. >500W/m^2) are not achievable given the available solar resource. This situation does not alleviate the contractor from completing all testing included within the commissioning requirements. However, some of the tests which are not safety related can be deferred, provided all safety related tests have been completed.

Table 1 – Seasonal Testing Considerations

Testing Requirement	Safety Related Testing	Deferred Testing Allowed	Comments
Insulation Resistance Testing	Yes	No	Tests should be undertaken during wet, or damp conditions to simulate worse case conditions.
Polarity Test	Yes	No	Polarity checks shall be completed on every system.
Open Circuit Voltage (Voc)	Yes	Yes	Initial Voc shall be completed on each individual string prior to interconnection to a common bus with other strings. Comparison to related strings should only occur under consistent conditions.
Short Circuit Current (Isc)	No	Yes	This relates to performance of the string and is not strictly speaking a safety related test. This test must be completed under consistent conditions.

I-V Curve Tracing	No	Yes	This testing must be completed under adequate irradiance (as defined herein) and should be deferred to clear sky conditions between April and September
Continuity to ground Tests	Yes	No	All ground continuity testing shall be completed prior to system energization.
IR Imaging	Yes	Yes	IR Imaging is safety related, and if possible, should be undertaken. Where it is not possible due to conditions, care should be taken to ensure connections are torqued and testing takes place early in the spring.

7.4 Commissioning Responsibility Matrix

The specific responsibilities may vary from project-to-project depending on the scale, scope of project and level of involvement of third-party commissioning representatives (e.g. Commissioning Authority for the base building may oversee some testing for specific New Construction projects etc.). The following table provides a template for the standard commissioning approach. Contract documents should be adjusted to reflect the project specific approach:

Table 2 – Commissioning Responsibility Matrix

Task		Activity	Deliverable(s)	Responsible Party
Commissioning Field Activities	Installation Verification and Testing	Contractor to complete a visual inspection of the full system. Contractor to complete installation verification checklists which includes insulation resistance testing and Voc records of DC strings.	Test Results Installation Verification Checklists (IVCs)	Contractor
	Initial Set-Up of Inverters & System Startup	Initial set-up of all inverters following all manufacturer guidelines including system startup.	Manufacturer FAT Reports System Startup Report	Contractor
	Engineer Site Review	Contractor to assist Engineer by providing access to electrical equipment. Inspection activities will include all electrical aspects of this system, including the monitoring system.	Detailed Site Review Report (by Engineer)	Engineer
	Wires Service Provider Commissioning	Contractor to assist Engineer by providing access to electrical equipment for Wires Service Provider required COVER test.	COVER Testing & Approvals	Commissioning Authority
Reporting	Wires Service Provider AC Commissioning Report & Final Approvals	Engineer will assemble all documentation required to ensure system is commissioned to the satisfaction of Wires Service Provider and is granted authorization to generate.	Wires Service Provider required commissioning.	Commissioning Authority
	Deficiency Reports	Engineer will assemble all outstanding deficiencies from all activities onsite.	Deficiency Report	Commissioning Authority
	Documentation of System	Provide remaining collection of system documentation including information as required by the system owner	O&M Manual	Contractor

7.5 Stage 0 – Prototype Array / Table Review

Where practicable, once the first sub-array, or table array (for ground mounted systems) has been completed (including complete wire management and terminations within the array, and at the inverter), a review should be undertaken with representatives of the design and construction teams including the City of Edmonton project staff, host facility operations staff, the engineer/consultants, and the Contractors responsible for the project. Together the team should review and agree on the site-specific implementation of benchmark standards, and construction guideline requirements. Corrections (if applicable) should be made and reviewed prior to building-out the rest of the system.

7.6 Stage 1 – DC Commissioning – Field Review & Testing

Upon confirmation that the DC portion of the system is complete, the Commissioning Authority will schedule the initial site visit to commence commissioning activities. The electrical contractor shall provide the following documentation at least two (2) business days prior to this visit:

- Completed installation verification checklists (IVCs) provided in Appendix B for items relating to the DC portion of the system. These will include (but are not limited to) torque value forms for fasteners, as well as, racking, module, and inverter inspection forms, all of which are to be completed by the contractor(s) during construction.
- Cut sheets for equipment on the DC side of the inverter. This may include information for grounding lugs, transition boxes, and modules.

Prior to arriving onsite, the Commissioning Authority will review the documentation listed above for compliance with the design and manufacturer requirements. Any concerns will be addressed during the site review.

7.6.1 DC Inspections:

The first review shall focus on the workmanship of the installation with respect to performance, durability, reliability and safety for the DC portion of the system. As part of the review, the Commissioning Authority will complete the following inspection tasks:

- Visual review of connections and terminations of conductors (including polarity), as well as assembly of fasteners, fittings and joints
- Review of the wire management to ensure that conductors are properly supported and protected
- Visual inspection of racking system, including "spot checks" of racking-to-structure (where applicable) connections and module-to-racking connections.
- A comprehensive review of the grounding/bonding strategy to verify continuity from the modules through to the inverter as per CEC requirements.
- A review of installed modules, all DC equipment (including fuses), and DC conductors to verify that they conform to the "Issued for Construction" drawings and supporting documents and are installed properly.
- A review of labeling for compliance with the CEC and Owner's requirements. This includes string, transition box, and combiner box (i.e. inverter) labeling

7.6.2 DC Testing:

In addition to the inspection tasks noted above, Commissioning Authority will also carry out the tests listed below and outlined in Protocol 1, 2 and 3. All electrical testing will be performed in accordance with the IEC 62446 international standard, and will only be carried out with a minimum irradiance of **500 W/m^2**. If the weather conditions are not suitable, the site visit will be rescheduled to a more appropriate date.

Table 3 – DC Testing Acceptance Criteria

Required Testing	Protocol #	Acceptance Threshold	Comments
Insulation Resistance Testing	1	Varies based on Operating Voltage	Applied test voltage to be ≥ equipment operating voltage provided permission has been granted by the manufacturer
Polarity Test	2	Pass/ Fail	Verified with suitable equipment prior to energizing equipment
Open Circuit Voltage (Voc)	2	+/- 4% from expected	Irradiance during testing shall be at least 500W/m^2, but ideally >650 W/m^2 *NOTE: errors in string wiring resulting in different string lengths being connected to a common bus can result in current flow. This poses a real risk to workers and could damage equipment. Ensure all strings on a given MPPT are the same length and match the drawings.*
Short Circuit Current (Isc)	2	+/- 5% from expected	Irradiance during testing shall be at least 500W/m^2, but ideally >650 W/m^2
MLPE	2	+/- 2% from expected	Validate all optimizers (or MLPE units) are reporting and functional. Download operating data to confirm proper power output.
I-V Curve Tracing (If Applicable)	2	+/- 4% of mean	Curve characteristics and output values will be reviewed to ensure string performance is acceptable
Continuity to ground tests for DC bonding/grounding components	-	Pass/ Fail	Continuity checks to be performed at multiple locations throughout the array

Results of the DC tests listed above will be recorded onsite and incorporated into the final commissioning report in accordance with the Owner's commissioning requirements. If module level power electronics (e.g. optimizer, or microinverter) are utilized and can provide module performance data. A summary report of those parameters demonstrating satisfactory performance is acceptable as an alternative to string level testing.

Areas of concern or deficiencies noted during review of the documentation and visual inspections and/or testing will be documented, along with suggested corrective action (as applicable), in a commissioning site review report. This report will be issued within five (5) business days of the issue being identified and will list action items that need to be resolved prior to moving onto Stage 2. All deficiencies identified shall be addressed by the contractor prior to turning over the PV system to the City of Edmonton.

7.7 Stage 2 – AC Commissioning - Field Review & Testing

Upon confirmation that the AC portion of the system is complete, the Commissioning Authority will schedule a site visit in coordination with the Contractor to continue commissioning activities. The Contractor will provide the following documentation at least two (2) business day prior to this visit:

- Completed Insulation Resistance Test Report for all conductors between the point of common coupling and inverters shall be populated as part of the Installation Verification Checklists (IVCs).
- Completed Installation Verification Checklists (IVCs) provided in Appendix B for items relating to the AC portion of the system. These will include (but are not limited to) insulation resistance values for AC

conductors from the inverters to the grid connection, torque value forms for all fasteners, as well as, inverter and AC equipment inspection forms, all of which are to be completed by the contractor(s) during construction.

- The Factory Acceptance Test (FAT) Report for each of the inverters (as generated specifically for those units) will be reviewed and incorporated into the documentation package. These test reports will indicate that the Under and Over Frequency and Voltage criteria are met in accordance with IEEE1547.
- Electrical Contractor to provide confirmation of final electrical inspection certificate, and contractor redline markup of SLD.

Like Stage 1, the Commissioning Authority will review this documentation for compliance with the design and manufacturer requirements before arriving onsite and discuss any concerns during the site review.

7.7.1 AC Inspections:

During AC review the focus will be to review the workmanship of the installation with respect to performance, durability, reliability and safety for the AC portion of the system. As part of the review, the Commissioning Authority will complete the following inspection tasks:

- Visual review of connections and terminations of conductors, as well as fittings and joints.
- Review of the wire management to ensure that conductors are properly supported and protected.
- A comprehensive review of the grounding/bonding strategy to verify continuity through the AC portion of the system as per CEC requirements.
- A review of the inverter, all AC equipment (including fuses, disconnects, transformers, etc.), and the AC conductors to verify that they conform to the "Issued for Construction" drawings and supporting documents.
- A review of labeling for compliance with the CEC and Purchaser's requirements. This includes inverter, disconnect, transformer, metering, and switchgear/service entrance labeling.

Areas of concern or deficiencies noted during our review of the documentation, visual inspections and/or testing will be documented, along with suggested corrective action (as applicable), in a commissioning site review report. This report will be issued within five (5) business days of the issue being identified and will list action items and areas of concern that need to be resolved prior to moving onto Stage 3. All deficiencies identified shall be addressed by the contractor prior to turning over the PV system to the City of Edmonton.

7.7.2 AC Testing:

The AC testing is focused on verifying correct operation of the system, validating trip response (e.g. anti-islanding) or trip settings. Specific requirements on a project-by-project basis (depending on scale and type of protective relays or passive anti-islanding measures) will be determined by EPCOR as the wire service provider.

Project teams should refer to the *EPCOR Generator Interconnection Technical Guide for Edmonton – section 5.4 Commissioning Test* for specific requirements associated with the Distributed Energy Resource (DER) connection requirements.

The Contractor will be responsible for operating the system at all stages of testing. The contractor is responsible for having verified initial startup (in a load state, not generating state) of the inverters and associated controls, and completed all initial setup and programming required.

Table 4 – AC Testing Acceptance Criteria

Required Testing	Protocol #	Acceptance Threshold	Comments
Frequency Operation / Range	4	59.3 Hz to 60.5 Hz	Confirm frequency is operating in the range of 59.3Hz to 60.5Hz
Power Factor	4	0.9 to 1.1	Testing to be undertaken at a minimum irradiance of 500W/m^2
Maximum Harmonic Current Distortion	5	(5%)	Testing to include logging up to the 40th interval, and shall demonstrate compliance with CSA Table 1 values
Steady State Conditions ▪ Output Power ▪ Current ▪ Voltage ▪ Frequency ▪ Harmonics ▪ Power Factor	4	See above	Log for 5-minute intervals during normal inverter operation. .
Cease to Energize Testing (same as Unintentional Islanding)	3	Disconnects in 0.16 s	Metering equipment shall be connected inside the exterior Wires Service Provider isolation disconnect.

The Commissioning Authority shall prepare the Testing report. The contractor shall provide any additional requested documentation or test results prior to being submitted to the Wires Service Provider (e.g. EPCOR) for final review and approval. EPCOR reserves the right to witness any and all commissioning tests and shall be notified in at least five (5) business days in advance of when the system will be tested.

7.8 Stage 3 – Performance Ratio Testing & Monitoring System Commissioning

This site visit will involve a variety of tasks required to verify proper operation of the PV system and output in accordance with the Owner Contract Requirements: *Performance Test must meet or exceed the following standard: at least **95% percent** of the installed AC Capacity.*

Table 5 – PRT Testing Acceptance Criteria

Losses	Minimum	Maximum	Expected	Notes
Apparent Soiling	97.0%	99.0%	98.0%	To be noted from site observations
PV Module Power Tolerance	100.0%	103.0%	101.5%	Per manufacturer datasheet
DC Wiring Losses	99.0%	99.5%	99.0%	To be based on calculated losses
AC Wiring Losses	98.0%	99.0%	98.5%	To be based on calculated losses
Inverter Efficiency	97.5%	98.5%	98.0%	Per Inverter Manufacturer Curves
Overall Expected Range	**~92.5%**	**~97.5%**	**~95.0%**	**Acceptance thresholds all to be +/- 3%**

This visit will be scheduled for a day when there is adequate irradiance (i.e. >500 W/m^2) and will take place once the system is fully operational and the monitoring system has been installed, programmed, and is operational.

As part of this review, the Commissioning Authority will complete the following activities:

Monitoring System Commissioning: During the morning of this visit the Commissioning Authority will witness the commissioning and calibration of the monitoring system per manufacturer requirements. Proper operation will be verified by comparing readings made by the monitoring system to field measurements made with handheld standalone equipment.

System Performance Verification: If unable to complete during prior site visits, the system performance verification task will be completed at this time, as described above.

Areas of concern or deficiencies noted during our review of the documentation, visual inspections and/or testing will be documented, along with suggested corrective action (as applicable), in a commissioning site review report. This report will be issued within five (5) business days of the issue being identified and will list action items and areas of concern that need to be resolved prior to moving onto Stage 4. All deficiencies identified shall be addressed by the contractor prior to turning over the PV system to the City of Edmonton.

Table 6 – Performance Testing Criteria

Required Testing	Protocol #	Acceptance Threshold	Comments
Performance Ratio Testing	7	Generates ≥ nameplate capacity	By direct measurement or by calculation, the Instantaneous Yield will be verified.

7.9 Stage 4 – Infrared Thermal Imaging Scans

Infrared Thermal Imaging shall take place when the system is operating at or above 60% of the full nameplate capacity and after the system has been operating for a half hour at or above that capacity. The Contractor shall retain the services of at least a Certified LEVEL 1 Thermographer who shall carry out infrared thermal scans of all equipment and field connections required to ascertain the correct operation of the system. This includes inverters, AC panelboards, transformers, DC/AC switchgear and DC/AC inverter connections.

Table 7 – AC/DC System Imaging

Stage 4 – AC / DC System Imaging			
Required Testing	**Protocol #**	**Acceptance Threshold**	**Comments**
AC Connections	6	5° C asymmetry in connections	All field terminations will be reviewed for thermal anomalies that may suggest high resistance (poor) connections and other defects.
DC Connections	6	5 °C asymmetry in connections	All field terminations will be reviewed for thermal anomalies that may suggest high resistance (poor) connections and other defects.
Module Imaging	6	10 °C variation in Cells	Measured variation in cell temperature for cells within a given module.

A technical condition memo which comments on the state of the system at the time of the visit shall be issued to the City of Edmonton. If areas of concern are identified, this memo would be expanded to identify those areas, recommended next steps, and would include digital and infrared images highlighting the concern. The credentials of the thermographer, and valid calibration certificate for the camera used shall be submitted with the report.

8 Post-Construction Documentation

8.1 Contract Documents

All relevant contract documents generated during construction shall be included in the final package provided to the City of Edmonton. This will include change orders, site instructions etc. which amend or clarify the original contract documents issued for the project.

8.2 As-Built Documentation

The contractor shall provide redlined markups of all variations from the contract documents that were encountered throughout the construction process. These redline drawings shall be accompanied by photographs of any aspects which cannot be reviewed directly (e.g. trenched conductors, within wall chases etc.). The Engineer-of-Record is responsible for reviewing these markups and updating a complete set of construction documents for record purposes. These record drawings shall be provided to the City of Edmonton for their as-built records.

8.3 Professional Site Reviews

All site reports provided by the City of Edmonton, its designated consultant (e.g., engineers, architects) or a third-party related to the solar photovoltaic system construction shall be responded to by the contractor in writing. All major action items and minor deficiencies shall be addressed, the resolution documented, and supporting photographs, report, or measurements provided to resolve the deficiencies. Any deficiencies which require seasonal testing or witnessing shall be included in the final punch list for the project.

8.4 Operation & Maintenance Documentation

The system documentation must be available in draft form prior to commissioning and shall be provided to the City of Edmonton project staff. The Operation & Maintenance Manual shall include the following information (under separate labeled tabs for each item). Please refer to *SCHEDULE 3 – Operations & Maintenance Manual checklist* for a summary of the items to be included within the manual.

8.5 Commissioning Reports

The commissioning report(s) shall be provided as part of the close-out documentation. This shall include all test results, onsite verification, and baseline data that was recorded for the system. This report will be a comprehensive document identifying the commissioning activities undertaken and will include:

- DC Verification Results
- AC Verification Results
- EPCOR Commissioning Report
- Performance Test Results
- Infrared Imaging Results

Where applicable the commissioning report shall be signed and sealed by the responsible parties confirming that the commissioning tests have been completed and comply with the Authorities Having Jurisdiction requirements.

8.6 Onsite Training

Once the system is complete, commissioned, and fully operational, the Contractor shall provide an On-Site Training Session to demonstrate the typical operation of the system for the City of Edmonton project staff, and host facility staff to go over all the operating parameters of the system.

This training shall also include an overview of required operations & maintenance (O&M) related activities and required access to complete those activities. This training shall also include an overview of the monitoring system and related web-based platform.

8.7 Warranties

The contactor is responsible for registering all equipment with the manufacturers and coordinate the submission and approval by the OEM for warranty information. All warranties shall be registered in the name of the City of Edmonton, and all documentation shall be dated for the date of energization (or an alternative date as agreed upon by the City of Edmonton).

PROTOCOL 0 – System Isolation Procedures

In working around solar photovoltaic systems - particular care must be taken to observe and follow warning labels reading “DO NOT DISCONNECT UNDER LOAD” located on module connections, combiner boxes, disconnects, and some inverter switches not designed as a load-break switch. Failure to heed these warning labels can lead to equipment malfunction, arcing, fires, and personnel injuries.

- Before servicing the PV system, ensure staff have read all operating instructions or are familiar with the various pieces of equipment. Specific attention should be paid to inverter requirements.
- All system components must be assumed to be energized with maximum DC voltage (up to 1,000V) until personnel verify that the voltage has been removed from all sources.
- All current carrying conductors shall be assumed to have current until verified with a clamp-on ammeter and checking for the presence of both AC and DC current. This is specifically critical for components such as string fuse holders, and module Quick Connects which are not rated to be disconnected under load.
- All enclosure doors should remain closed with latches tightened, except when they must be opened for maintenance or testing (e.g. IR imaging).

Inverter Isolation

To isolate inverters, it is necessary to turn them “OFF” using any integral soft-start/stop options. For inverters not equipped with an integral on/off switch or an Emergency Stop button, it will be necessary to turn the systems off using the disconnect switches attached to or located near the inverters. Do not open switches that are specifically labeled “**Do not disconnect under load**” until a load-break switch has been opened and current flow is stopped. Generally, the first available upstream load-break AC switch or circuit breaker is safer to operate first (before the dc switch), because the inverter instantly shuts down the transistor bridge when AC voltage is removed. Once the system is off, the remaining switches can be opened and the system can be locked out until the fault condition is repaired or it is safe to turn it back on.

For conducting any service work within an inverter, it is necessary to open and lock-out the AC and DC disconnects. NOTE: That opening the DC disconnect integral to the inverter will stop current flow but does not “de-energize” the inverter as string input conductors, terminals and associated fuse holders will still typically be energized. The exception may be systems equipped with remote rapid shutdown or module level electronics designed specifically to reduce voltages to below 96V at the module (e.g. RSD optimizers or microinverters).

Always use a DC clamp on the meter to confirm there is no current passing through ungrounded conductors in the combiner box or inverter prior to opening any fuse holders or locking connectors. NOTE: Fuse holders indicated as “touch safe” are only safe to touch in the fully closed position (and even then, it is not recommended to make contact without appropriately rated gloves). A shock hazard exists while those fuse holders are opened or closed and insulating gloves with appropriate leather protectors are required to ensure safe servicing and replacement of fuses. Plug type fuse holders are not touch safe and so gloves and insulated tools must be used to remove them.

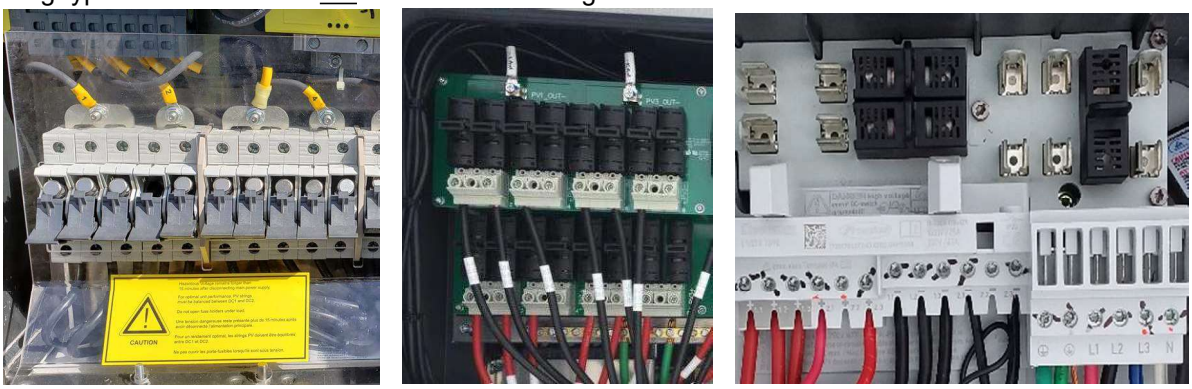


Figure 15 – Examples of DC String Fuse Holders

If further isolation of the inverter is required (such as for inverter equipment replacement), the design and construction guidelines make reference to the use of quick connects that are to be placed on strings coming into the inverter to properly isolated the strings. After confirming there is no current flow with a DC clamp meter – disconnect all home run cables so the inverter is fully deenergized.

It should be noted that for inverter equipment replacement, the bonding connection from the array must not be disturbed without a temporary bonding jumper installed to ensure the bonding path is uninterruptible, as noted within *Volume 3 – Construction Guidelines*.

Combiner Isolation

Combiners are treated much the same way as inverters – with the difference being that current flow should be interrupted using integral disconnects (or by shutting down the upstream inverter) to ensure no DC current is flowing when attempting to isolate strings or fuses:

Use a clamp-on DC current meter to confirm that the homerun does not have any current passing through it, and then disconnect the string by opening the homerun positive and negative connectors and putting insulating caps (as made by the quick connect manufacturer) on the source circuit connectors.

Combiners that are connected in parallel will have DC voltage on both sides of the disconnect switch (where more than one combiner feeds a single MPPT section of an inverter). In this scenario, all combiners connected in parallel must be opened and isolated to provide isolation to electrically interconnected combiners.

Prior to commencing any work within the combiner box use a DC voltmeter to confirm that each string has been successfully isolated, and that the main terminals are also properly de-energized.

Modules & String Isolation

After turning off the inverter, switches, and combiner boxes and isolating the combiner boxes from the array using the procedures noted above - proceed to isolate all strings from the electrically interconnected sub-array by removing string fuses (or slugs) so that each string is independent. This is important to ensure an inadvertent issue does not permit reverse flow of power from adjacent strings. Grounded arrays may require the use of grounding chains (refer to figure 4) – maintenance staff should never rely on inverter GFDI fuses for a proper connection to ground.

Figure 16 – Temporary Grounding Chain

Before disconnecting any string, use a DC current rated clamp-on meter to confirm there is no current passing through the string.

- Do not open module-to-module connection (on a source circuit) without first confirming that there is no current flowing on the circuit.
- Use the appropriate manufacturer specific connector unlocking tool to disengage the module connector
- Repeat for each module or string to be isolated from the system and cap all connections.
- If modules are removed from a system, even temporarily, technicians must ensure that the equipment grounding system remains intact for the remaining modules and all exposed connections are properly capped.

PROTOCOL 1 – Insulation Resistance Testing (IRT) Procedure

Preparation:

1) Individuals involved in testing shall wear appropriate PPE, including high voltage gloves, eye protection, hardhats, vests, and safety footwear.

2) All disconnects (i.e. inverter) shall be in the OFF (or OPEN) position and conductors shall be removed from OCPD terminals (or in the case of fuses OCPD removed or deactivated).

3) Individuals involved in testing shall avoid contact with any metallic or potential grounding pathways (in the event that a ground fault occurs).

4) All circuits to be tested shall be deenergized and isolated from sensitive equipment (e.g. power conditioning electronics etc.).

Parameters

System Voltage (Voc STC x 1.25)	Test Voltage	Minimum Impedance (IEC 62446)	Acceptance Criteria
120 V	250 V	0.25 MΩ	25 MΩ
< 600 V	500 V	0.5 MΩ	50 MΩ
< 1000 V	1000 V	1.0 MΩ	100 MΩ
<1500 V	1500V	1.5 MΩ	150 MΩ

Procedure

1.) Verify that there is bonding continuity of the racking system and the modules through to the building ground reference used for the tests.

2.) Zero out the test lead resistance by following the manufacturer procedure for the Test Device.

3.) Test the insulation resistance of each DC string in the combiner box (i.e. inverter) by following the steps below:

a. Isolate all strings from inverter / combiner and from the string of modules before testing.

b. For AC circuits test prior to terminating conductors

c. Connect the Test Device to ground.

d. Connect the red lead (+) to the positive homerun string conductor.

e. Connect the black lead (-) to the negative homerun string conductor.

f. Secure test leads as necessary (i.e. cable ties, or other means).

g. Follow the Test Device instructions to perform the test for a sustained time period of at least 1 minute (60 seconds) of sustained voltage.

Repeat these steps for all strings in the combiner box (i.e. inverter).

NOTE: Ensure components are de-energized, before removing test cables.

PROTOCOL 2 - Voc / Isc / IV Curve Tracing Procedure

Preparation:

1.) Individuals involved in testing shall wear appropriate PPE, including high voltage gloves, eye protection, hardhats, vests, and safety footwear.

2.) All DC disconnects (i.e. inverter) shall be in the OFF (or OPEN) position and all OCPD shall be removed or deactivated.

3.) Individuals involved in testing shall avoid contact with any metallic or potential grounding pathways (in the event that a ground fault occurs).

Parameters

The Performance Factor (PF) is the key factor that we are assessing as part of this evaluation. The PF is a numerical representation of how the string is performing compared to normalized results at Standard Test Conditions (STC). We anticipate a distribution of +/- 5%.

Procedure

1.) Isolate all strings at the combiner box (i.e. inverter) by opening all touch-safe fuse holders or removing the OCPDs. (A touch-safe fuse holder should still be operated using high voltage gloves as the DC strings are still live and the possibility of an incident is likely if there is a fault in the system.)

2.) Ensure the IV Curve Tracer is turned OFF.

3.) Connect the black lead (-) from the IV Curve Tracer to the negative bus.

4.) Connect the red lead (+) from the IV Curve Tracer to the positive bus.

5.) Test strings at the combiner box (i.e. inverter):

   a. Close the touch-safe fuse holder or replace the OCPD for the string to be tested.

   b. Turn the IV Curve Tracer ON.

   c. Stand back, and wirelessly engage the IV Curve Tracer.

   d. Review results, and if satisfactory record via software.

   Repeat this step for each string in the combiner box (i.e. inverter).

6.) If an issue is identified in a string complete the following steps:

   a. Review the I-V curve to ascertain the potential cause (i.e. series resistance vs. shunt resistance, vs. possible shading).

   b. Conduct a visual review of the affected string to determine if there are any causes that may be readily apparent.

   c. Remove any dust, debris, or possible shading factors, and re-test the string.

   d. If the string still performs below the acceptance criteria – isolate the individual modules and conduct individual IV testing on each module.

   e. If all modules test out properly, reconnect and retest the entire string. If a module fails the test, have it removed and sent for warranty review.

PROTOCOL 3 - Anti-Islanding AC Testing Procedure

Preparation:

1.) Individuals involved in testing shall wear appropriate PPE, including high voltage gloves, eye protection, hardhats, vests, and safety footwear.

2.) Prior to connecting the Power Quality Meter (PQM) all equipment shall be isolated with switches and disconnects in the OFF (or OPEN) position.

3.) To commence testing, all DC and AC disconnects (inverter and isolation disconnects) shall be in the ON (or CLOSED) position and all OCPD shall be installed or otherwise activated.

4.) Individuals involved in testing shall avoid contact with any metallic or potential grounding pathways (in the event that a ground fault occurs).

Parameters

The test will be considered to have passed provided the following criteria is met:

- Upon loss of AC Grid Voltage – the inverters cease to energize.
- Upon return of AC Grid Voltage – the inverters monitor the grid for 5 minutes (300 seconds) before starting to generate again.
- During all times when the inverters are not to be operating, there is no current being generated at the terminals (i.e. after disconnect is opened, or for 5 minutes after it is re-closed).
- All steady-state parameters are in accordance with the criteria established in Protocol 4 – AC Electrical Test Procedure.

Procedure

1.) Connect the Fluke 435 II to the load side of the exterior disconnects using the supplied voltage clamps and flex current clamps.

2.) Start by engaging all disconnects and turning the inverter control switches to ON position. Once the inverters have seen grid voltage, verify visually that the 300 second countdown occurs and take note of when the inverters start to generate power.

3.) Monitor all outputs, and after 1 minute of generation has elapsed, the main exterior DG disconnect switch will be tripped OFF (or OPEN) to simulate an outage.

4.) All inverter outputs will be tested to ensure that the inverters have ceased to energize during the simulated utility outage. DG disconnect switch must remain OFF (or OPEN) for a minimum of 2 minutes.

5.) Upon confirmation of step 4, the main exterior DG disconnect switch shall be turned ON (or CLOSED). Ensure all inverter outputs are monitored to verify that the system has ceased generation and does not restart until after the 5 minutes (300 second delay), as per (CSA 22.3 107.1/UL1741).

6.) After the inverters begin producing power, the steady-state parameters of the system will be monitored, and recorded, for a minimum of 5 minutes, as per step 3.

PROTOCOL 4 - AC Parameters Functional Testing

Preparation:

1.) Individuals involved in testing shall wear appropriate PPE, including high voltage gloves, eye protection, hardhats, vests, and safety footwear.

2.) Prior to connecting the Power Quality Meter (PQM) all equipment shall be isolated with switches and disconnects in the OFF (or OPEN) position.

3.) All DC and AC disconnects (inverter and isolation disconnects) shall be in the ON (or CLOSED) position and all OCPD shall be installed or otherwise activated.

4.) Individuals involved in testing shall avoid contact with any metallic or potential grounding pathways (in the event that a ground fault occurs).

Parameters

Steady-state parameters will be monitored and recorded using an IEC 61000-4-30 Class A Certified Power Analyzer. Recording interval time must be ≤ 0.5sec. Power Analyzer must have waveform capture capability. Parameters monitored shall comply with the following values:

Parameters	Acceptance Criteria	Referenced Standard
Voltage	Voltage variations at the point of common coupling are limited to +/- 6% of the nominal voltage	CSA C22.2 No. 257-06 Clause 5.2.3
Frequency	Confirm frequency is operating in the range of 59.3Hz to 60.5Hz	CSA C22.2 No. 257-06 Clause 5.3.21
Power Factor	Power Factor is within 0.9 and 1.1	CSA C22.2 No. 257-06 Clause 5.3.13

Procedure

1.) Prior to system start-up, the steady-state parameters listed in this section will be monitored, and recorded, for a minimum of 1 minute on the line side of the exterior disconnect (Point A).

2.) DG system will be turned on upon the completion of Step 1

3.) Upon system start-up, the steady-state parameters listed in this section will be monitored, and recorded, during the inverter start up cycle

4.) Once the inverters begin to produce power, the steady-state parameters listed in this section will be monitored, and recorded, for a minimum of 5 minutes

5.) During normal operation, the steady-state parameters (output power, voltage, current, frequency, harmonics and power factor) of the system will be monitored, and recorded, for a minimum of 1 minute

PROTOCOL 5 - Harmonics Testing

Preparation:

1.) Individuals involved in testing shall wear appropriate PPE, including high voltage gloves, eye protection, hardhats, vests, and safety footwear.

2.) Prior to connecting the Power Quality Meter (PQM) all equipment shall be isolated with switches and disconnects in the OFF (or OPEN) position.

3.) All DC and AC disconnects (combiner box, inverter, and isolation disconnects) shall be in the ON (or CLOSED) position and all OCPD shall be installed or otherwise activated.

4.) Individuals involved in testing shall avoid contact with any metallic or potential grounding pathways (in the event that a ground fault occurs).

Parameters

The test will be considered to have passed provided the following criteria is met:

- Upon reaching steady state operation, the harmonic distortion values shall comply with the CSA C22.2 No107.1 Table 15 – see excerpt below:

Limits of current harmonic distortion*		
	Maximum distortion	
Harmonic numbers	Even harmonics, %	Odd harmonics, %
2nd through 9th	1.0	4.0
10th through 15th	0.5	2.0
16th through 21st	0.4	1.5
22nd through 33rd	0.2	0.6
Above 33rd	0.1	0.33

Source: CSA C22.2 No. 107.1, Table 15.

Table 1: Limit of Current Harmonic Distortion

Procedure

1.) Connect the Fluke 435 II to the load side of the exterior/utility disconnect using the supplied voltage clamps and flex current clamps.

2.) Start by engaging all disconnects and turning the inverter control switch to ON position. Once the inverter has connected and the output is steady engage the harmonics logger. It is recommended that power output be >90 % during testing, however, depending on system specifics, test can be performed at lower output.

3.) Through onscreen readouts, verify that the Total Harmonic Distortion of current THD generated by PV System is less than the limits identified above.

4.) Monitor all outputs, for a minimum of 5 minutes of power flow to ensure a consistent result is logged.

PROTOCOL 6 – Equipment Infrared Imaging

Preparation:

1.) Individuals involved in testing shall wear appropriate PPE, including an Arc Flash suit as required by the system rating, high voltage gloves, hardhats, vests, and safety footwear.

2.) Prior to system energization, all protective guards on equipment must be removed so that the temperature of conductors can be measured as close as possible to points of connections. This includes all plastic shields which are clear in the visible light spectrum but opaque in the infrared spectrum.

3.) A licensed electrician shall be on hand to energize the system, including bypassing safety interlocks required to energize the system.

Prior to commencing IR imaging, the AC DG#1 disconnect shall be locked out to ensure that the AC system is de-energized. Then all enclosures shall be opened, voltage checks made to ensure de-energization, the handles shall be bypassed, and plastic guards removed to facilitate proper imaging. This preparation work shall be complete while the system is de-energized.

The removal (prior to imaging) and reinstallation (following imaging) of all safety covers, doors, or protective layers shall only be done when the AC portion of the system (and equipment being accessed) are fully isolated. Under no condition should equipment covers, or guards be removed while the solar photovoltaic system is in operation, or while AC portion of the system are energized. Staff shall wear appropriate PPE for de-energizing and re-energizing equipment.

Parameters

The test will be considered to have passed provided the following criteria is met:

- Operation shall be achieved with the system operating >60% of its nominal output)
- Equipment shall include calibrated infrared cameras operated by certified thermographers.
- Thermal Images (upon desktop review of images) displays no obvious hot spots, and all conductors/connections are within an acceptable limit as deemed by a certified thermographer. After images are acquired onsite, the thermographer shall “thermally tune” images using software to ensure that they can be easily interpreted by the system owner. If allowed by the software, notes should be added to each file describing any pertinent details associated with the image.
- The test will be considered to have passed the IR survey criteria provided a desktop review of images by a certified thermographer and it is recommended that the classification of temperature differentials and the directed course of action is as follows:

Table 8 - Thermal Imaging Acceptance Criteria

Classification	Temperature Difference	Action Required
Normal	0 to 5ºC	No action
Low Grade	5 to 10ºC	To be monitored – plan new inspection
Medium Grade	10-35ºC	Repair at scheduled shut down
Severe	> 35ºC	Repair immediately or isolate sub-system impacted.

Procedure

1.) Infrared imaging activities will be scheduled for a day when the sky is clear of clouds, the wind speed is low, the system is operational, and all modules are clear of snow cover. All images must be acquired when there is adequate irradiance (i.e. > 500 W/m2). Thermal images may only be acquired when the wind speed at the outdoor equipment is below 10 km/hr to minimize the effect of convective heat transfer.

2.) Prior to IR Imaging, the system shall be run for no less than 60 minutes (1 hour) to ensure that the system has reached a steady state condition prior to imaging. System output during the "warm-up" period and at times during imaging activities shall exceed 60% of the rated nameplate AC power output value.

3.) For each piece of equipment that is imaged, record the electrical load in amps (i.e., output current at disconnects, etc.) along with the ambient temperature, reflected temperature, and relative humidity. Prior to imaging at each location, ensure that the infrared camera is adjusted for the ambient temperature, humidity, reflected temperature, and emissivity so that these attributes are stored within the infrared image files.

4.) All images must be acquired while taking special care to consider the spot size ratio of the camera so that the temperature of all conductors and connectors can be accurately measured using post-processing software. Images must be in focus and taken at 5 to 15 degrees from being perpendicular to the object. Each thermal image must be accompanied by a visible light (i.e. digital) image.

5.) Equipment that is located outdoors (if applicable) and in direct sunlight must be shaded for a period of time to negate any impact that solar radiation has on the temperatures inside the equipment. This is typically done with an umbrella held at a distance to shade the equipment.

6.) When imaging conductors, the composition of images should be such that the reviewer can compare the temperatures of at least two (preferably three) adjacent conductors.

PROTOCOL 7 - Instantaneous Yield Test

Preparation:

1.) Individuals involved in testing shall wear appropriate PPE, including high voltage gloves, eye protection, hardhats, vests, and safety footwear.

2.) All DC and AC disconnects (inverter and isolation disconnects) shall be in the ON (or CLOSED) position and all OCPD shall be installed or otherwise activated.

3.) Individuals involved in testing shall avoid contact with any metallic or potential grounding pathways (in the event that a ground fault occurs).

Parameters

Steady-state irradiance of 500 W/m2 or greater is required. Inverter(s) output should not be at full power. or clipping excess DC array input power. If the array is composed of multiple sections with varying tilt, azimuth, equipment, or other factors, the test shall be run for each section. The Expected Instantaneous Electrical Power shall be determined by the following equation:

$$P_E = P_{STC} \times \frac{I_{meas}}{I_{STC}} \times \left\{1 + \left[C_T \times \left(T_C - T_{STC}\right)\right]\right\} \times \text{Derate} \times \text{Error}$$

Where:

P_{STC} = the sum of the flash-tested power of each module installed
I_{meas} = the pyranometer measured in-plane irradiance (W/m^2)
I_{STC} = 1000 W/m^2
C_T = the module temperature coefficient
T_C = the measured cell temperature
T_{STC} = the module temperature at STC (25ºC)
Derate = the system derate (TBD based on equipment selected for each project)
Error = 0.97 (account for measurement errors, non STC irradiance, and minor variances)

Procedure

1.) Operate the system with the parameters as described above.

2.) Collect three datasets for all variable outline within the equation listed above.

3.) Calculate the Instantaneous Yield using data collected and equation listed above.

4.) Verify Instantaneous Yield satisfies the Owners requirements of delivery Gross Nameplate capacity.

5.) Alternate method can be used - Provide monitoring output summary indicating system generated Gross Nameplate Capacity.

SCHEDULE 1 – Pre-Mobilization Checklist

Project Name:	Site Address:	Date of Submission	Submitted by
Facility Number:		**System Size (kW_{AC})**	**DC Capacity (kW_{DC})**

☐ **Staging Plan –** this plan shall include the following information at a minimum:

- ☐ **Mobilization Area** – a context drawing showing location on site where site trailer (if applicable) will be located, and equipment will be stored until it is staged on the building/site.
- ☐ **Fencing** – include overview of all temporary fencing that will be installed to prevent unauthorized access to the site (both locations and details).
- ☐ **Protection** – indicate any surfaces that will be protected (at grade, on the roof etc.) and what means of protection will be provided.
- ☐ **Parking** – provide an indication of parking for contractors (either offsite or onsite).
- ☐ **Signage** – include details regarding signage to be posted onsite during construction to redirect traffic (pedestrian and vehicular).

☐ **Roof Access Plan –** this plan shall include the following information at a minimum:

- ☐ **Permanent Roof Access** – Identify where permanent roof access points will be, and how they will be used by construction staff.
- ☐ **Temporary Roof Access** – identify the location and details of any temporary access means, such as stair towers, or other scaffolding structures will be positioned / used by staff.
- ☐ **Crane Access** – identify where cranes will be positioned, the operational arc for lifting materials and landing points for materials on the roof.
- ☐ **Lift Access** – identify where lifts will be used, reach distance, and what they will be operating over. Ensure if lifts are being used to access the roof that appropriate railings and docking measures are employed (e.g. lift bridge, or adequate reach).
- ☐ **Bump Lines** – Indicate location and positioning of bump lines on the roof that will be in place during construction.
- ☐ **Railings / Barriers** – indicate where railings or other temporary barriers will be in place to protect workers from live edges (roof edges skylights etc.)
- ☐ **Tie-off Locations –** indicate where any tie-off locations will be installed, or temporary tie-off devices used. Include range based on length of safety lines used.

☐ **Permits & Approvals –** ensure all permits and approvals are completed including Buildiner Permits, Electrical Permits and other permits as may be required by AHJ.

☐ **Shop Drawings –** ensure all relevant Shop Drawings have been submitted (refer to SCHEDULE 2 for shop drawing submission details.

SCHEDULE 2 –Shop Drawing - Submission Checklist

Project Name:	Site Address:	Date of Submission	Submitted by
Facility Number:		**System Size (kW_{AC})**	**DC Capacity (kW_{DC})**

	Reviewed	Reviewed as Noted	Revise & Re-Submit
Racking	☐	☐	☐
Bonding Lugs	☐	☐	☐
PV Modules	☐	☐	☐
DC Conductors	☐	☐	☐
Inverter	☐	☐	☐
Optimizer (or MLPE)	☐	☐	☐
Rapid Shutdown Device/s	☐	☐	☐
Combiner Box (if used)	☐	☐	☐
Overcurrent Protection	☐	☐	☐
Disconnects/Switches	☐	☐	☐
Combiner Panel/s	☐	☐	☐
Transformer	☐	☐	☐
AC Conductors	☐	☐	☐
Monitoring System	☐	☐	☐

SCHEDULE 3 – Operation & Maintenance Manual – Submission Checklist

Project Name:	Site Address:	Date of Submission	Submitted by
Facility Number:		**System Size (kW_{AC})**	**DC Capacity (kW_{DC})**

- ☐ Contact information for the Contractor (e.g. address, phone number, email address)
- ☐ Name of system designer including list of engineers-of-record involved in the project (and role)
- ☐ Basic system information
  - Power (DC/AC wattage)
  - Design criteria detailed, e.g. design temperatures for inverter operation
  - Standard design parameters
- ☐ Photovoltaic Racking Shop Drawings (sealed by the Engineer-of-Record).
- ☐ For every product listed in Shop Drawing Submittals:
  - Product data sheets, manuals & approved shop drawings
  - Product serial numbers documented
  - Manufacturer Warranty Documentation for every product listed
- ☐ Fuse/Breaker schedule – including spare parts model numbers
- ☐ As-Built Documentation (sealed by the Engineer-of-Record).
- ☐ Installation Verification Checklists
- ☐ Commissioning Test Results (raw data format)
- ☐ Commissioning Report
- ☐ Deficiency list – with an indication of all items having been resolved and notation on action taken.
- ☐ Instructions for semi-annual and annual maintenance required for an IEEE 1547 compliant installation.
- ☐ Documentation that all necessary approvals, permits, and inspections from the Authorities Having Jurisdiction have been obtained (include copies of any permits, or close-out letters).
- ☐ Documentation of permission from the Wires Service Provider (EPCOR) to energize the system.

SCHEDULE 4 – Installation Verification Checklists (IVC's)

Project Name:	Site Address:	Date of Submission	Submitted by
Facility Number:		**System Size (kW_{AC})**	**DC Capacity (kW_{DC})**

The Installation Verification Checklists shall be submitted in a spreadsheet / raw data format to provide a baseline dataset for future operations & maintenance activities. These checklists are included in a template format however they should be tailored to address the site specific equipment:

- ☐ Overall System Review Checklist
- ☐ Module & Racking Checklist
- ☐ DC-AC Equipment Checklist
- ☐ AC Cables (test results)
- ☐ AC Voltage Check (test results)
- ☐ DC Voc Check (test results)
- ☐ DC Cables (test results)
- ☐ Monitoring Checklist

These checklists and forms shall be completed by the Contractor and provided to the Engineer-of-Record prior to them attending site for an as-built system review.