City of Edmonton
Solar Photovoltaic Program

Design Guideline

Volume 2

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INTEGRATED INFRASTRUCTURE SERVICES
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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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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 design guideline is to create a basis of design for solar photovoltaic projects deployed on City of Edmonton facilities. This guideline is to be read in conjunction with all the relevant codes and standards (per Section 2.0) and has been developed to consider not just initial installation, but also provisions for the safe and effective deployment of systems and ongoing maintenance and operation of the facilities. This guideline document defines the acceptable approach for designing solar photovoltaic systems that are to be installed on City of Edmonton Facilities. It does not alleviate any responsibility from the engineers-of-record from their responsibility to design a code compliant system that is authenticated in accordance with APEGA requirements. Ultimate responsibility for the design and engineering of the systems rests with the Engineer-of-Record (EoR).

1.1 Purpose & Scope

This guideline document is for use by either design 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 approaches that the City of Edmonton will accept for its projects. It is to be read in conjunction with *Volume 3 – Construction Guideline* for specifics around the installation 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 (e.g. 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

The consultant or contractor is responsible for ensuring the system design adheres to all applicable referenced standards. These standards include (but may not be limited to):

2.1 Design 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)*
- *Canadian Electrical Code (CEC) Part 1 – C22.1-18 (24th Edition)*
- *National Building Code – 2019 Alberta Edition (NBC(AE))*

2.1.2 Technical Standards

Canadian Standards Association (CSA)

- *CAN/CSA C61215-08 - Crystalline silicon terrestrial photovoltaic (PV) modules*
- *CSA/ANSI C450-18, Photovoltaic (PV) module testing protocol for quality assurance programs.*
- *CSA-C22.1-18, Canadian Electrical Code, Part I*
- *CSA-22.2-107.1, General Use Power Supplies*
- *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*
- *519-14, Recommended Practices and Requirements for Harmonic Control in Electric Power Systems*
- *1584-18 - IEEE Guide for Performing Arc-Flash Hazard Calculations*

Underwriters Laboratory (UL)

- *UL - 1703, Standard for Flat-Plate Photovoltaic Modules and Panels*
- *UL - 1741 SA, Standard for Inverters, Converters, Controllers, and Interconnection System Equipment for Use with Distributed Energy Resources*
- *ULC/ORD C-1703-01 PV Module Safety Standard*
- *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)*
- *Design & Construction Standards (Volume 1 – General)*
- *City of Edmonton Solar Photovoltaic Program – Volume 1: Site Selection Guideline*
- *City of Edmonton Solar Photovoltaic Program – Volume 3: Construction Guideline*
- *City of Edmonton Solar Photovoltaic Program – Volume 4: Operations & Maintenance Guideline*
- *City of Edmonton Solar Photovoltaic Program – Volume 5: Asset Management Guideline*

3 Host Facility Standards

The building that will support the solar PV system (either directly, or on the same property where the interconnection is made) is referred to as the Host Facility. This facility may be operated directly by the City of Edmonton or by a third-party tenant depending on the specific case. Regardless of the arrangement, the specifics associated with deployment of a solar photovoltaic system on a City owned facility is the same.

3.1 General Expectations

3.1.1 Site Access Requirements

Any personnel accessing a site either at the design stage, or during operation shall follow the same procedure. Access to any site 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 permitted by the site operators, immediately upon arrival. All personnel accessing a site shall sign in with the reception or the facility operator notifying them of the intent of the visit, expected duration and emergency contact details. Before departing the site, all personnel shall sign-out and notify onsite facility staff as to the completion of their visit.

3.1.2 Roof Access Requirements

Where possible the specific roof access requirements shall be ascertained prior to arriving onsite. Where permanent access ladders (or stairways) are installed these must be used. If no permanent access is available, temporary access shall be considered, provided proper ladder safety requirements can be met. All personnel accessing the roof level shall ensure they stay on designated pathways and back from the roof edge as noted in section 3.4.5.4.

- **Flat Roof (<1/12 Slope)** – All projects that do not have permanent roof access to sections of flat roof where solar modules are to be installed shall include the addition of a safe access method as part of the solar project (refer to Roof Access Plan requirements). The method of access shall be determined in conjunction with the host facility operators. It could include a permanent access ladder or a receiver to support the safe access with temporary ladders. The specific solution will be determined by site specific conditions at the City of Edmonton's discretion.
- **Sloped Roof (>1/12 Slope)** – for sloped roofs where a permanent ladder is not practicable, consideration should be given to how the roof would be accessed through temporary ladders, or lifts. This consideration shall include travel distance and landing points for service personnel to safely access the array in the unlikely event that equipment is damaged and needs to be replaced. Roof access to regularly serviced equipment (e.g. combiners or disconnecting means) shall be accessible without the use of a lift.

All Regularly Serviced Equipment shall be Readily Accessible to ensure that the system can be effectively serviced and maintained. The design team shall include a Roof Access Plan as part of their initial design package to confirm the approach to roof access is acceptable to the City of Edmonton.

3.1.3 Recording of Existing Conditions

Every effort should be made to record the existing conditions onsite during the preliminary engineering and review stage. This would include the condition of the roof, placement of equipment, pathways, wireways etc. Where a solar project is going to be deployed. This existing condition documentation is an important part of the facility maintenance records. Refer to Schedules 1 – 5 listed in the *CoE Solar Photovoltaic Program – Volume 1: Site Selection Guideline* for checklists to reference during both initial investigations and professional reviews.

3.2 Submittal Expectations

3.2.1 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:

Concept Design Package – This submission package (*refer to SCHEDULE 1 – Concept Design Package – Submission Checklist*) is to include at a minimum the following documents:

- **Site Plan** – a context drawing showing location of site, surrounding major roadways, site access and the proposed location of the major equipment e.g. array, interconnection point etc. (for smaller rooftop systems this could be combined with the roof plan).
- **Roof Plan –** a scaled drawing or rendering illustrating the extent of the array, existing rooftop obstructions, existing or proposed roof access, setbacks from the roof edge, around service pathways, and other obstructions.
- **Single Line Drawing –** a high level overview of the system including module and inverter configuration, balance of system equipment locations, DG project interconnection point, and equipment specifications.
- **Equipment Layout –** a drawing or photo markup indicating approximate size and location of major equipment (e.g. disconnects, inverters, combiner panels etc.).
- **Datasheets –** cutsheets for major equipment such as module, inverter, racking, and monitoring system.

Detailed Engineering Package – This submission package (*refer to SCHEDULE 2 – Detailed Engineering Package – Submission Checklist*) is to include an updated version of the documents submitted in the Concept design package – as well as the following additional documents:

- **Site / Roof Access Plan –** a scaled drawing or rendering illustrating the location of all Regularly Serviced equipment and how the design ensures they will be Readily Accessible. Indicate maintenance access pathways, limits of approach. Provide details on how Infrequently Serviced Equipment will be accessed – including any necessary equipment (e.g. lifts, booms etc.) as well as provisions for travel restraint and/or fall arrest.
- **Roof Staging Plan** – indicating location and bearing capacity of the roof to support equipment (e.g. PV modules) that are staged as part of the construction). Indicate where field verified locations (e.g. over top of columns or major beams) will require coordination onsite.
- **Electrical Details** – any detailed wiring diagrams to illustrate connection specifics, array configuration, grounding/bonding methods etc.
- **Mechanical Details –** any installation details relating to the mechanical installation of the racking, modules, conductors/cables and inverter/combiner mounting etc.
- **Equipment Schedules –** a high level overview of the system including module and inverter configuration, balance of system equipment locations and equipment specifications.
- **Labeling Diagrams –** a scaled drawing or diagram indicating labeling requirements, that can be used to produce labels for the project.

- **Wire Sizing & Losses –** a drawing or document summarizing wire loss calculations for all power related AC and DC conductors throughout the system.
- **Monitoring System –** a drawing outlining the monitoring system, components, interconnection, and wiring details necessary for a complete and functional system.
- **PVsyst (or equivalent) Generation Model –** a generation model based on the designed system and shop drawings of manufacturer specific equipment.

3.2.2 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. It is anticipated that only the Concept Design Package would be provided to the tenant for their review and comment. The City of Edmonton may choose to include a tenant review of the Detailed Engineering submission at their discretion depending on the nature of the project.

3.2.3 AUC Rule 007 Participant Involvement Program (PIP) Requirements

Prior to completing a micro-generation notice with EPCOR, a customer must notify and consult with stakeholders in accordance with Appendix A1 of Rule 007 – Participant involvement program guidelines:

- Power plants, less than 1 MW (urban)
    - Notification requirements: *"Provide notification to occupants, residents and landowners within the first row of occupied properties surrounding the proposed development and consider including areas beyond the first row of occupied properties surrounding the proposed development, as the circumstances require."*
- Power plants, 1-10 MW (urban)
    - Notification requirements: *"Provide notification to occupants, residents and landowners within the first row of occupied properties surrounding the proposed development and consider including areas beyond the first row of occupied properties surrounding the proposed development, as the circumstances require. Alternatively, notice of project-specific information to postal code addresses is sufficient to satisfy this communication requirement. If the applicant considers that certain landowners that should be notified of the proposed project may be missed because they do not reside at the property, additional efforts to notify them should be considered."*
    - Consultation requirements: *"Applicants should consider consultation to occupants, residents and landowners within the first row of occupied properties surrounding the proposed development, as the circumstances require"*

AUC Rule 007 Appendix A1 – Participant involvement program guidelines should be referenced for notification and consultation requirements. Any decisions to limit the scope of a Participant Involvement Program (e.g., No visibility to direct neighbours, etc.) should be made in consultation with the City of Edmonton. In all cases, regulatory risk should be limited by completion of a thorough PIP as per the requirements of AUC Rule 007 and 024.

3.2.4 Environmental Requirements

Prior to completing a micro-generation notice with EPCOR, consideration must be given as to whether the project meets the requirements of the Wildlife Directive for Alberta Solar Energy Projects and whether the system will require further environmental studies and planning.

The Wildlife Directive for Alberta Solar Energy Projects states that:

> *"Review by an AEP Wildlife Biologist is not required when solar energy projects are small scale (i.e., less than 1MW) or within urban areas as solar energy infrastructure has inherently low impacts on wildlife when integrated into an existing anthropogenic footprint such as on rooftops".*

For Micro-Generation projects larger than 1 MW and that are not explicitly contained within an urban 'footprint', a review by an AEP Wildlife Biologist and referral report may be required. For projects of any size, there are obligations under the wildlife act to use due diligence in looking for nests and dens and avoiding them during any ground mount construction project.

3.2.5 AUC Rule 012 Noise Control Requirements

For projects designed with central inverters or external transformers, a noise impact assessment may be required per the requirements of the AUC Rule 024 Rules Respecting Micro-Generation and AUC Rule 012 Noise Control. AUC Rule 012 should be referenced for permissible sound levels and noise impact assessment requirements.

3.2.6 Micro-Generation System Eligibility

Solar PV systems are eligible to be classified as Micro-Generation if they:

1. Are designed to meet all or a portion of the customer's total annual energy consumption at the customer's site or aggregated sites *and*
2. have a total nameplate (AC) capacity that does not exceed the lesser of 5 MW or the capacity of the electrical service *and*
3. supply electric energy only to a site that is located on property that the customer owns or leases *and*
4. is located on this property or property that the customer owns or leases that is adjacent to this property.

Historical annual energy consumption for the site or anticipated future energy consumption (as calculated and sealed by a professional engineer as per EPCOR requirements) should be referenced and compared to projected annual solar PV system generation to determine the upper limits of a system size to ensure eligibility under the Micro-Generation Regulation.

In cases where the electrical service size limits the solar PV system size and the electrical energy consumption allows for a larger installation, EPCOR may permit an upgrade to the electrical service (at the customer's cost) prior to the Micro-Generation application for a larger system.

Note that 'aggregated sites' means 2 or more sites that are:

1. located on property that is owned or leased by the same customer and
2. connected to a single electric distribution system feeder owned by one electric distribution system owner, and either
    a. enrolled with the same retailer, with each site charged at the same rate for the supply of electric energy, or
    b. enrolled with the same regulated rate provider, with each site charged at a regulated rate under a regulated rate tariff referred to in section 103 of the Act for the supply of electric energy.

3.2.7 Power Plant Application

The Micro-Generation Regulation allows for free and simple interconnection of solar PV systems. Solar PV systems should be designed to meet the requirements of the regulation in order to avoid the lengthy and costly development and approvals process otherwise required.

Solar PV systems that meet the requirements of the Micro-Generation Regulation may proceed without filing a power plant application under Rule 007: Applications for Power Plants, Substations, Transmission Lines, Industrial System Designations and Hydro Developments to the Commission if the construction or alteration and operation of the unit:

a. does not directly and adversely affect any person; (see section 3.2.3 – AUC Rule 007 Participant Involvement Program (PIP) Requirements) and,
b. does not have any adverse environmental impact; (see section 3.2.4 – Environmental Requirements) and
c. the unit is constructed or altered and operated, in compliance with Rule 012: Noise Control.

If any of the above criteria are not met, then an application must be submitted to the AUC per the requirements of AUC Rule 007 and AUC Rule 024.

The majority of City of Edmonton projects within the scope of this design guideline will meet the above noted criteria and therefore may proceed with an application and approval directly from EPCOR, the distribution facilities owner for the City of Edmonton. Any facilities that are not acceptable will be flagged by EPCOR. The application package for the Wires Owner (EPCOR) shall meet the requirements of the Micro-Generation Regulation and AUC Rule 024. This includes completion of:

1. EPCOR'S Form A – Micro-generation notice form
2. Electrical single line diagram
3. Site plan illustrating inverter and DG system disconnecting means locations
4. Inverter specification and applicable certification document(s)

Note that EPCOR will not accept a Micro-generation application for processing until an electrical permit has been obtained for the project. However, EPCOR may provide preliminary feedback on available interconnection capacity prior to a full application and should be engaged to mitigate risk with the interconnection and Micro-Generation application. EPCOR will complete detailed interconnection studies for any projects larger than 50kW on single phase or larger than 150 kW on three phase services. EPCOR advises that interconnection studies typically take two months which should be considered when determining project schedule and target in service dates.

All application packages shall be submitted once an inverter make/model has been selected for the project. Changes to the inverter configuration could result in having to amend the study with EPCOR and should be avoided where possible, variations in the DC array layout or module configuration will have minimal impact. EPCOR will provide feedback regarding the Supervisory control and data acquisition (SCADA) requirements for monitoring and control onsite as part of this consultation. It is expected that systems with a nameplate capacity of 250 kWAC or larger will require both monitoring and control, and designs shall include those provisions as part of the application.

3.2.8 Issued for Construction (IFC)

The Issued for Construction (IFC) package shall include all the information requested as part of the detailed engineering package but shall be sealed by the Engineer-of-Record and shall form the basis of the contract for proceeding into construction. Any proposed changes to the stamped IFC drawings shall be first submitted as contract documents (e.g. Site Instruction, RFI, Contemplated Change Notice etc.) and reviewed in detail by the EoR prior to approval.

3.2.9 Record Drawings

All existing record drawings that are referenced for the development of the project must be returned in the condition for which they were received by the consultant or contractor. All changes to the conditions onsite must be recorded within the as-built drawings. As-Built drawings shall comply with section 2.3.7 listed in *Vol 1 – CoE Consultant Manual*.

3.3 Safety Guideline

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, project consultants shall consider the following aspects in their design process:

3.3.1 Orientation

All staff engaged in project work, whether at the pre-assessment, design or construction stage are responsible for having completed the 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. Please consult with the City of Edmonton Occupational Health & Safety requirements specific requirements.

3.3.2 Hazard Identification & Control

At the design stage the specific controls relate primarily to engineering controls that "*involve changing the work environment to eliminate or physically control the hazard*. This can be achieved through design specifications, the use of substitution, isolation, enclosure and ventilation. Engineering controls are preferred where reasonable and practical. Through the design process hazards associated with the project implementation shall be considered and identified. This primarily translates to the following categories for solar photovoltaic projects:

- *Working at Heights* – placement of equipment and means of servicing the equipment should be included as part of this process. Equipment requiring frequent (defined as annual or semi-annual) review and retorquing, programming etc. shall be in a Readily Accessible location outside of the roof edge setback (min. **2000 mm (6.6 ft**)). Equipment that is not expected to have annual maintenance required and as such is Infrequently Serviced Equipment (e.g. PV modules, optimizers, microinverters etc.) can be located without access walkways and clearances etc. provided the Roof Access Plan identifies the method for replacing/repairing that equipment.
- *Height of Equipment* – any serviceable parts of equipment shall be installed as follows:
    - *Visual Requirements* - including displays and programming buttons shall not be higher than **1600 mm (~5.3 ft)** and no lower than **304mm (~1 ft)** off of the finished floor, grade or roof surface.
    - *Switch Operation* – for switches, breakers, and operable devices shall not be higher than **2000 mm (~6.5 ft)** off of the finished floor, grade, or roof surface.

  Where regularly serviceable equipment is proposed to be installed higher than the listed limits, a permanent working platform providing **1000 mm (~3.3 ft)** of clear space in front of the equipment, ladder anchor, or other means of ensuring safe access can be afforded.
- *Limits of Approach* – all equipment shall be placed in locations where at least **1000 mm (~3.3 ft)** (or greater as defined by CSA Z462 from energized components – when they are in an open/live position) of clear access can be afforded in-front of energized equipment. A stable, slip resistant working surface that is clear of obstructions must be provided immediately in front of all Regularly Serviced equipment.
- *Electrical Safety (e.g. shock and arc flash)* – The system should be designed to minimize the shock and arc-flash hazards associated with the equipment. This means providing appropriate means of isolation (see details in AC and DC section on specific isolation requirements) and control of hazardous energy.

Specific controls and requirements associated with Administrative Controls and Personal Protective Equipment (PPE) is addressed in section 3.1.2 in the *CoE Solar Photovoltaic Program – Volume 3: Construction Guideline*

3.3.3 Planned Safety Inspections

All site reviews associated with the design services shall include an initial safety inspection to identify hazards, note age of equipment and means of accessing equipment. Specific steps for subsequent investigation (e.g. switchgear interconnection details) shall be reviewed with City Staff to develop an approach that eliminates the risk to staff involved in those investigations.

3.3.4 Orientation and Training

Design documentation shall include requirements for Orientation & Training of City Staff and onsite operators about the system that is being installed. Details of the required orientation shall be included in the design documents please refer to section 3.1.1 in the *CoE Solar Photovoltaic Program Volume 3: Construction Guideline f*or orientation and training requirements.

3.3.5 Emergency Response Planning

The consultant shall ensure that emergency egress pathways are denoted on their design drawings. This is specifically required for rooftop layouts to illustrate that there is a clear means of egress from all areas with Regularly Serviced solar photovoltaic equipment. This information should be included in the Roof Access Plan, and any site specific signage for the project.

3.3.6 Site Safety Data Sheet (SSDS)

For each project the consultant shall prepare a Site Safety Data Sheet summarizing the operational hazards including operating voltages, shock hazards, arc-flash classification, boundary and rating for each piece of major equipment requiring access/review This summary shall be kept on file by the facility and referenced for all servicing work that is required on the facility. Refer to SCHEDULE 3 for a template SSDS form.

3.4 Architectural Guideline

3.4.1 Terms of Engagement for Architect/Landscape Architect

Where a project will be visible from the street or to the general public, at the City of Edmonton's discretion it may be necessary to engage the services of a design consultant to navigate any urban planning approvals.

3.4.2 Design Goals

These studies, evaluations and design work will inform the City of Edmonton, stakeholders, surrounding property owners and the public and assist in decision making for the best possible outcomes.

3.4.3 Visual Impact Assessment

Any projects that include rooftop, wall, or ground mounted solar photovoltaic arrays that are visible to the general public (or deemed to be visible by City staff) shall include renderings of the visual impact and associated implications included within the approval packages.

3.4.4 Urban Design Impact

Where the solar photovoltaic arrays will be between the building and the street address, or near the public right of way, an urban design impact review may be required as may be deemed necessary by the Planning Department.

3.4.5 Roof Mounted Arrays

3.4.5.1 Setbacks

Roof setbacks will vary depending on the roof mounted deployment (pitched roof or flat roof) and site-specific conditions. However, minimum setbacks are required, as noted below, and additional setback considerations may be required for some specialized equipment (not already included in the list in Table 3 – section 3.6.1). All proposed layouts shall be approved by facility maintenance staff as part of the design submittal and review process.

3.4.5.2 Pitched Roof Edge

The minimum setback for pitched roof systems (i.e. >1/12 pitch) is **1000 mm (~3.3 ft)**. Both flush mounted and clamped fixed tilt racking systems must include this minimum roof edge clearance.

3.4.5.3 Pitched Roof Access Pathways

Flat roof systems must maintain a **450 mm (1.5 ft)** access pathway for every sequence of **16 to 18 m (~50 to 60 ft**) depending on string length to allow safe access and mobility throughout the array. The rails that bridge these access pathways shall be physically decoupled to prevent thermal expansion issues, but electrically bonded to maintain the bonding path integrity.

3.4.5.4 Flat Roof Edge

The minimum roof edge setback for flat roof systems (i.e. <1/12 pitch) is **3000 mm (~10ft)** to maintain ARCA requirements from roof edge and comply with Occupational health and Safety requirements.

3.4.5.5 Flat Roof Access Pathways

On flat roofs, a **1200 mm (4 ft)** access pathways shall be provided throughout the array and shall connect to all major rooftop mounted equipment that require parts replacement or servicing. For clarity, this does not include roof drains, vent stacks, or other penetrations that only require cleaning and not consumable parts.

3.4.6 Wall Mounted Arrays

Although it is expected that fewer systems will be deployed on walls (as compared to roofs) there are specific requirements that apply to integration into existing wall systems. Wall mounted arrays shall meet the requirements of the City of Edmonton Zoning Bylaw, section 50.7. Solar modules mounted to the wall of a building may project a maximum of:

- **600 mm** into an interior Side Setback, provided a minimum of **600 mm** is maintained between the property line and the Solar Collector; and
- **1500 mm** into all other Setbacks, provided a minimum of **600 mm** is maintained between the property line and the Solar Collector;

Where a solar array is mounted to the wall of a building and projects into an interior Side Setback, the total length shall not exceed one third of the length of the wall it is mounted to.

3.4.6.1 Accessibility

Systems shall be designed so that equipment is not readily accessed by the public. If the height from the finished grade is such that a member of the public could come into contact with the solar modules, wiring, or associated equipment than barriers or means of preventing unauthorized access to components shall be included within the design in accordance with CEC requirements. Attention should be paid to providing a reasonable means of access to qualified professionals who may be required to service the equipment as part of the operations and maintenance program.

3.4.6.2 Cladding System Compatibility

All materials used on the solar photovoltaic array shall be galvanically isolated (where metallic cladding systems are used) from the façade cladding system materials. The design approach should also consider thermal expansion and contraction and variation between the cladding and the fixed solar racking and framing members.

The exterior wall's cladding system must therefore be rigid enough to accommodate these additional stresses. Exterior cladding types that tend to have higher resistance to wind forces include:

- Stucco
- Pre-cast concrete panels
- Cast-in-place concrete
- Wood siding

Exterior wall cladding types that will require additional review and consideration include:

- Metal panel

- Fibre-cement panel and siding
- Vinyl or aluminum siding

Metal panels, and fibre-cement panel and siding tend to be more flexible and placement of the PV system should be carefully planned so that the cladding is not permanently damaged where they are the most vulnerable to flexural stresses.

Due to its relative fragility, exterior wall cladding assemblies equipped with vinyl or aluminum siding should be avoided, though wall-mounting a PV system on a vinyl or aluminum siding wall is possible. If a building with vinyl or aluminum siding is scheduled to be equipped with a wall-mounted PV system, renewal with a more durable and longer-lasting cladding system should be considered as part of the project. If the wall being considered to receive a new PV system is a rainscreen system or concealed barrier behind the exterior cladding, careful consideration is required to ensure PV system anchors are correctly detailed at the face of cladding, but also at the concealed air and/or moisture barrier to as not compromise the barrier. For walls with rainscreen cavities, transferring the load across the cavity should also be addressed in the detailed structural design.

3.4.6.3 Anchoring Method

The means for anchoring the array must be specific to the substrate (e.g. concrete, steel wood), support spacing, and stand-off requirements of the specific cladding system. All structural tie-ins shall be designed and stamped by a professional engineer licensed to provide services within Alberta. Where not immediately obvious, design teams are encouraged to work with City Staff to get as-built verification of wall assembly and underlying structure.

3.4.6.4 Flashing

Projects should incorporate flashing that integrates with the building aesthetics, and which can be removed to permit servicing of the modules if that becomes necessary. Consideration of air flow and ventilation behind the modules should be made to meet module manufacturer's requirements and for improved performance. Where flashing is being used as part of a rodent protection solution, openings in flashing shall not exceed those stipulated by the CEC 64-210 and the relevant *Standata Electrical Safety Information Bulletin 18-CECI-64*.

3.4.7 Ground Mounted Arrays

Whether the array is constructed as part of a purpose-built carport or as a standalone conventional ground mount system the requirements shall be consistently applied.

3.4.7.1 Accessibility

Any systems that are accessible to the general public (i.e. not positioned behind a fence equipped with access control) shall be designed such that unauthorized persons cannot inadvertently contact energized parts or components. In such cases, consideration should be given to utilizing design strategies which minimize the number of accessible components (e.g. module level optimizers or micro-inverters as opposed to string level inverters) and operating voltage of the system.

3.4.7.2 Snow Clearing (for Carports)

Provisions shall be made to facilitate the clearing of snow immediately under and around the carports. Planning should be in place to shed, where practicable snow away from travel lanes. The structural design and placement of structural members of the carports shall consider how snow clearing can be effectively addressed. The site plan provided as part of the design review submission process shall include an approach for snow removal.

3.4.7.3 Foundations

The foundation design shall consider site specific soil conditions and, where practicable, the amount of foundation elements above grade shall be minimized to facilitate access in and around the structures. It is reasonable for small scale installations (i.e. fewer than 12 piles) to avoid extensive onsite testing and instead proceed on a limited basis taking into consideration soil conditions in the area.

3.4.7.4 Piles

All piles shall be constructed of either galvanized steel or aluminum. If the soil conditions are acceptable and the aesthetic requirements of the project necessitate it, at the direction of the Architect or City Staff, powder coated piles could be considered. All ferrous piles shall have some means of preventing corrosion (e.g. hot dip galvanization, or appropriately applied paint).

3.5 Structural Guideline

3.5.1 Introduction and Design Approach

Structural scope for new ground mounted structures independent of the existing building structure shall be carried out in accordance with current code requirements, and the requirements of the City of Edmonton Integrated Infrastructure Services Consultant Manual Volume 1 & 2. The structural guidance presented in the following sections will be focused on impact to existing structures.

Structural scope for installations affecting the base building structure including roof mounted, wall mounted, and ground installations above and below grade structures, will include the following phases:

1. Investigation
2. Structural assessment
3. Design of reinforcing (if required)

The investigation phase is required to gather required as-built information on the structural elements for the purpose of carrying out the assessment and reinforcing design phases. The assessment phase will require evaluation of the current load carrying capacity of the existing structure. Based on the results of the assessment, structural reinforcing may be required. Further discussion on structural modifications is presented in section 3.5.5

3.5.2 Onsite Investigation Requirements

The requirements of field level investigation beyond the Level 2 Field review will be largely dependent on the available construction documentation available from initial design and any subsequent renovations. The engineer of record shall be responsible for determining what investigations are required for the purposes of assessing the current load carrying capacity and determining required reinforcing. The table below provides examples of field level investigations that may be required.

Table 1 - Structural System Investigation Methods

Existing Structural System	Material Type	Solar PV Compatibility	Investigations
Cast-in-Place Concrete	Concrete, reinforcing (rebar)	High	GPR Scanning, X-ray scanning, localized chipping to expose reinforcing, concrete core to test concrete compressive strength
Structural Steel	Steel, open web steel joists, W sections, Channel, HSS	High	Detailed as-built measurements, steel sample to test steel strength, steel thickness measurements (HSS)
Pre-Cast Concrete	Concrete, reinforcing (rebar / pre- or post-tension strands)	High	GPR Scanning, X-ray scanning, concrete core to test compressive strength.
Mass Timber	Timber	Low	Detailed as-built measurements, timber type and state, moisture measurements

Investigations may or may not be carried out by the engineer of record, in many cases subcontracts with service providers for scanning and material testing will be required. Coordination for site access scheduling, removal of finishes (which may or may not require abatement), and appropriate access to structural elements will be required.

3.5.3 Design Loads Methodology

The design loading to be used in both the assessment and structural design of modifications shall be in compliance with current building codes. Commentary L of the 2015 National Building Code provides guidance on the evaluation and upgrading of existing structures. Although Commentary L allows for some relaxation of the Principal Load Factors in the evaluation (assessment) and design of upgrade to existing structures, the City of Edmonton as the Authority having jurisdiction requires that all assessment and design activities for this scope be carried out per the requirements of Part 4: Structural Design of the National Building Code – 2019 Alberta Edition (NBC(AE)). Modified Principal Load factors in Commentary L shall not be applicable since the addition of a solar photovoltaic system is considered a change-of-use for the facility.

Importance Factor: Per the current intended use of the facility. Refer to descriptions of the importance categories in the current code.

3.5.3.1 Dead Load

1. Self-Weight: Roof assembly and self-weight of the structure.
2. Superimposed Dead Load or Collateral: Allowance for interior finishes, suspended mechanical and electrical equipment. Review base building drawings to determine existing allowance. For the purposes of the assessment, it may be feasible, given existing conditions (e.g. services/finishes suspended from the structure) to use a portion of the design allowance used in the initial design for a portion of the new Photovoltaic array. Depending on the site conditions and requirements, the following allowances should be maintained at a minimum:
    a. Suspended Ceiling: **0.25kPa**
    b. Mechanical/Electrical: **0.25kPa** for sprinklers and miscellaneous conduit, **0.4kPa** for heavier services.
3. Photovoltaic array: Additional global loads, and effects of localized point loads on the structure to be considered.
4. Existing Rooftop Equipment: Any equipment in the vicinity of the proposed photovoltaic array shall be included. Current locations, equipment geometry, and operating weights shall be determined. Snow accumulation adjacent the existing equipment shall be included. See 3.5.3.2.

3.5.3.2 Snow/Rain Load:

1. Base Snow/Rain Load per current requirements (NBC(AE)).
2. Additional Snow accumulation at roof projections including existing mechanical equipment, screens, high to low roof transitions. Snow accumulations at existing projections shall be determined based on ABC 2019.
3. Photovoltaic arrays impact the distribution of snow on a roof's surface. There aren't any specific requirements related to snow accumulation behavior at Photovoltaic arrays in NBC(AE), nor the NBC 2015 commentary. Pending a snow study based on the proposed facility and module layout, the snow accumulation shall be based on the current code provisions for roof projections.
4. A Snow Study may be warranted to verify the behavior and accumulation of snow given the project specifics, including: array height, structural area affected, layout of array on structure, and the potential for unbalanced snow accumulation to have a negative impact on the structural system.
5. The photovoltaic array system shall be reviewed to determine the effect on roof drainage and the potential for ponding that may affect the roof loads.

3.5.3.3 Wind Load:

1. Per current requirements (NBC(AE)).
2. For rooftop installations:

   a. Ballast, and connection loads for clamping and penetrating systems, to be designed in accordance with NBC 2015 Commentary I 'Roof Mounted Solar Arrays'. These loads are to be provided by the photovoltaic array manufacturer.
3. For wall mounted arrays:
   a. loads on array modules shall be designed in accordance with the Code, considering the array as a cladding element. Localized impact of these loads at the array connection points shall be reviewed.

3.5.4 Serviceability

All serviceability requirements per the current code shall be included in the assessment and design criteria for the work. Reinforced elements (where applicable) shall be accessible for inspections and where reinforcement can be affective by operational activities (i.e. FRP reinforcement) appropriate signage and labels shall be included.

3.5.5 Structural Modification Considerations

If the existing structure does not have the capacity to support the new loads or exceeds code defined deflection requirements, then reinforcing and/or supplementing the existing structure will be required. Reinforcement consists of adding materials to the existing structural elements to increase their structural capacity or stiffness (steel rod welded to joist chord). Supplementation consists of adding new structural elements to carry the additional load on the structure or prevent excessive deflection due to the change in load configuration. Examples of supplementation may include new beams and/or columns and/or foundations.

Loads on the structure shall be as noted in 3.5.3 with the exception of the following:

1. For the purposes of reinforcing design, it is recommended that the full base building collateral allowance be maintained.
2. If the area being reinforced contains mechanical, electrical or other service equipment that may be nearing its end of life, confirm with the City of Edmonton, if load allowances for future equipment are desired.

The desired method of structural modification shall be presented to the stakeholder group per the requirements of the City of Edmonton Integrated Infrastructure Services Consultant Manual Volume 1. Structural modifications must take into consideration the following factors:

1. Site use, and access for construction/installation activities
2. Removal of finishes, including potential abatement required for reinforcing installation
3. Removal of services for construction/installation activities
4. Impact to facility maintenance and use
5. Costs

Several options for structural reinforcing are presented in the table below. However, as noted, the final solution will be based on coordination with the City of Edmonton stakeholder group. All reinforcement options must also be tailored to address the site-specific conditions and constraints identified during the investigation stage.

Table 2 - Structural Reinforcement Options

Structural System	Structural Modifications
Cast-in-Place Concrete	Adding steel elements (plate) FRP (Fiber Reinforced Polymer)
Structural Steel	New steel elements welded to existing steel members. New secondary steel members. New beams/columns.

Pre-Cast Concrete	Adding steel elements (plate) FRP (Fiber Reinforced Polymer)
Mass Timber	Adding steel elements (plate) New secondary timber members. New beams and columns

Design of new composite structural elements shall be designed in accordance with NBC(AE) and applicable material/design codes.

3.5.6 Additional Documentation Requirements

The documentation required to be submitted for City of Edmonton review, approval and records are as follows:

1. Investigation:
   a. Notice prepared by the engineer of record describing the investigations to be carried out on site.
   b. Upon completion of the investigation, a letter prepared by the engineer of record describing the investigations and summarizing the results. Any scanning, or materials testing reports developed as part of the work shall be included.
2. Structural assessment:
   a. Letter report prepared by the engineer of record. The report shall include background information, description of structure, design loads and any assumptions, results of the assessment, and recommendations.
      i. Summary of all relevant background information available related to the existing structure.
      ii. Detailed description of existing structure in the area of proposed work.
      iii. Summary of investigation findings. Investigation report to be appended for reference.
      iv. Assessment methodology, design loads and all assumptions.
      v. Results of the detailed analysis, including confirmation of load path.
      vi. Recommendations, including schematic reinforcing options.
3. Design of reinforcing
   a. The documentation for the reinforcing scope shall comply with the requirements of the City of Edmonton Integrated Infrastructure Services Consultant Manual Volume 1. Note, the assessment report noted above may be included in the schematic design report for the structural scope.

3.6 Mechanical Guideline

As part of the Design Package, provide a roof plan drawn, indicating all existing mechanical equipment located in the area of interest. This equipment is to be shown at scale; for this purpose, the roof plan scale shall be selected such that the equipment is visible. At all locations where equipment is labeled and carries a manufacturer nameplate, provide the information on the drawing (i.e. “EF-5 – exhaust fan #5”, “RTU-3 – Rooftop unit #3”).

Age and condition of the existing equipment in the vicinity of the proposed array shall be assessed. Recommendations for replacement considering the age of the equipment and impact on the structure shall be provided during the initial design stage and incorporated into the overall design.

3.6.1 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). The summary of the minimum clearances is as follows:

Table 3 - Setback Provisions

Obstruction	Minimum Clearance/Setback	Note
Skylights	2000 mm (~6.6 ft)	Although not specified by OHS, skylights should be treated similar to a roof edge, if a walkway is required near skylights then this setback should be increased to match the roof edge.
Access Pathways	1220 mm (~4 ft)	This is for the access between any rooftop-mounted mechanical unit, and any means of egress or designated exit pathways defined by the Alberta Building Code.
Rooftop Equipment	2000 mm (~6.6 ft)	Air Handling, Rooftop Units (RTUs), Cooling Towers, Chillers etc. that are regularly serviced equipment.
Rooftop Utilities	610 mm (~2 ft)	Roof anchors, Natural gas lines, Condenser water supply/return lines / glycol lines, existing power supply wiring.
Roof Drains and Plumbing Vents	610 mm (2 ft)	Provide clearance on full perimeter of equipment to ensure potential removal/replacement
Rooftop in-take or exhaust ports and fans	915 mm (3 ft)	Wall-mounted louvers, Roof-mounted on penthouses, Goose-neck type ducts or any other type and chimneys/vents/stacks.
Wall-mounted in-take or exhaust ports	915 mm (3 ft)	Louvers, grilles, ducts etc.
Utility Service Entrances	3000 mm (10 ft)	This relates to electrical service conductors >750V and gas / water utilities.
Exhaust Fans	2000 mm (~6.6 ft)	Measured from the base of the fan curb.
Furnace Stacks	1220 mm (~4 ft)	Array layout should also further take into consideration shading of vent stacks on the array.
Cooling Towers	3000 mm (10 ft)	Where screening exists around the cooling tower this setback should also take into consideration shading by tower and screening.
Generators	2000 mm (~6.6 ft)	Array layout should also further take into consideration shading of generator and associated vents on the array.

At any point where obstructions cross access pathways, reflective tape to warn workers of a trip hazards shall be installed. Where obstructions are over **450 mm (~1.5 ft)** wide and/or **300 mm (~1 ft)** high, and may intersect access pathways, they shall be furnished with a bridge/step to permit safe crossing. Please note, minimum clearances are required, as noted above, for each piece of equipment to ensure proper maintenance and repair activities can be completed safely and efficiently without the interference of Solar PV equipment disrupting those practices.

All rooftop layouts must be approved by Facility Maintenance Services on a case-by-case basis to ensure the proposed locations of equipment (e.g. PV modules, racking etc.) do not detrimentally impact the existing maintenance plan and facility servicing requirements.

3.6.1.1 Equipment Access

Specialized rooftop equipment such as roof top units, furnaces, etc. should be reviewed to ensure that there is adequate access for servicing. The system design shall consider future removal and replacement requirements for base-building equipment and assemblies. Consideration should be given to systems that may be reaching their end-of-life to ensure that provisions for new units which may be larger and heavier than the original units. Where uncertainty exists, photographs shall be provided to Facility Maintenance Services for their review and comment.

3.6.1.2 Access Pathways

Indicate all points of access to the roof (e.g. stairwells, ladders, etc.) on the roof access drawing. Show all proposed access routes to the mechanical equipment and utilities, relative to the PV module layout on the roof plans. The access routes shall be as stipulated above (without interference from any PV module or racking equipment) and shall allow unobstructed access to all mechanical equipment and utilities.

3.6.1.3 Servicing Considerations

As noted above, layouts must be pre-approved by Facility Maintenance Services to ensure the proposed locations of equipment do not interfere with the access of existing equipment. It should be noted that this access is for servicing the equipment and does not refer to access required to replace that equipment.

3.6.1.4 Replacement Considerations

Replacement of full pieces of rooftop mounted equipment is considered a significant capital event and provisions would need to be made to remove and reinstall portions of the solar project if required. Consultants and contractors should consider configuring the system (e.g. stringing) so portions of the system can be removed without impacting full system operation. For example, leaving gaps in rails or the array along roof seams, or planning for isolating portions of the array to facility base building equipment replacement or system renewal. Localizing DC strings so that they do not span different roof levels or sections where practical.

3.7 Electrical Guideline

The minimum electrical requirements are clearly defined in the Canadian Electrical Code (CEC) and are not to be deviated from unless written approval from the City of Edmonton Safety Codes, Permits & Inspections (SCPI).

3.7.1 Interconnection Requirements

Interconnection requirements are clearly defined by the Canadian Electrical Code (CEC) in *Section 64-112 Interactive point of connection*. The design team shall review the main service switchgear, switchboard or fused disconnect onsite and with the manufacturer (where applicable) to determine the acceptable point of connection and means of connecting to the breaker, bus, or terminal. Where further investigation is required by the contractor as part of the construction scope this needs to be clearly detailed within the design documents.

Table 4 - Interconnection Options

Connection Location	Type of Connection
Existing / New Breaker	The breaker connection shall be made at the opposite end of the bus from the main supply breaker. Total combined ampacity (calculated based on trip settings) shall not exceed 120% of the bus capacity rating in accordance with CEC Section 64-112. Dedicated DG breaker to meet bus connection requirements and match the existing type/rating of the existing load breakers installed for the load facility. DG breaker to meet or exceed the existing current interrupting rating of the switchgear and be fully coordinated with the main service breaker prior to final commissioning.

Load Side Tap	Where a connection is made to the busbar on the load side, the location and sizing must be in accordance with CEC Section 64-112 and shall be made using switchgear manufacturer approved bus tap, and irreversible crimps on all conductors.
Line Side Tap	Where the bus bar rating of the switchgear is a concern, it is possible to connect on the line side of the main breaker. This connection location must be downstream (on load side of metering) of the meter (in relation to the grid) and the connection must be made in a method approved by the switchgear manufacturer. In the case of a line side connection on a fused service rated disconnect, additional lugs may be required to accommodate the connection. To be assessed during the initial site investigate phase (if possible).

Where the condition or capacity of the switchgear or related interconnection equipment is unsuitable for making the termination. It is the responsibility of the solar project to include for the costs associated with upgrading the associated electrical infrastructure.

All interconnection options noted above must be made at the main service entrance. Where interconnection in the main service entrance (e.g. main switchgear) is not feasible, any alternative main solar connection point will need to be pre-approved by the City of Edmonton during the concept design stage.

3.7.2 Isolation Disconnect

Regardless of interconnection method (refer to Table 4) an appropriately sized disconnect device, labeled "***Distributed Generation Disconnect #1***" or "***DG Disconnect #1***" shall be installed within the maximum distance specified by the CEC. It shall be labeled in accordance with the labeling requirements in Section 5.12 Labeling & Identification and it shall be the designated lock-out tag out (LOTO) location for isolating the PV system from the building electrical system.

Technical Rationale

Fusing the main DG Disconnect #1 provides a consistent and known point for throttling fault current to the solar photovoltaic system. It allows designs to specify a fixed fuse curve (as opposed to an adjustable trip profile common to many breakers) to provide operational consistency across all of the CoE projects.

This disconnect shall always be fused (even if the upstream connection method uses a breaker) and will be considered the "start" of the solar PV system. This disconnect is to be the demarcation point between the solar contractor and the base building electrical contractor for the installation, and servicing of the equipment. Where an upstream breaker is installed, that breaker shall be referred to as the **DG Disconnect #0** and labeling associated with "DG OCPD – Do not modify or relocate" shall be included on the switchgear along with all other CEC mandated labeling and signage.

Where space constraints make it impossible to install a separate disconnect in the main electrical room – an alternative solution should be reviewed with City of Edmonton staff in accordance with applicable CEC requirements. Acceptable alternatives would be to equip the breaker with LOTO hasps and include signage/labeling identify where the main system disconnect is located (e.g. either the utility isolation disconnect or rapid shutdown initiator).

3.7.3 Wiring

All conductors terminated within the switchgear and running to DG Disconnect #1 shall be Copper (Cu) and all terminations shall be made with factory provided lugs or using irreversible compression terminals (including DG associated bonds and grounding). This will minimize the thermal cycling and potential for connections to loosen in a location that is difficult to isolate for servicing.

3.7.4 Electrical Maintenance 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. In reviewing these standards, specifically relating to solar photovoltaic systems, the following limited approach boundaries would apply to all exposed conductors, devices, or connections:

Table 5 - Limited Approach Boundary

Common PV System Voltages	Limited Approach Boundary	CSA Z462 Reference
AC - 208, 240, 480, 600 VAC	1.0 m (3.5 ft)	Table 1A page 58
DC – 40-60 VDC*	1.0 m (3.5 ft)	Table 1B page 59
DC – 600, 1000 VDC	1.0 m (3.5 ft)	Table 1B page 59
DC – 1500 VDC	1.5 m (5 ft)	Table 1B page 59

*PV module Open-Circuit voltages at extreme low temperatures (e.g. -20C)

For clarity CSA Z462 states that the boundaries apply when conductors or apparatus are NOT insulated. This means identifying locations where energized conductors could be exposed (i.e. quick connects) and ensuring those points of exposure are within the array by the requisite distance.

To avoid having additional setback buffer applied to the entire array – the module orientation and string design shall take into consideration maintaining those distances from quick connects, and home run terminations where 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 and positioned away from walkways).

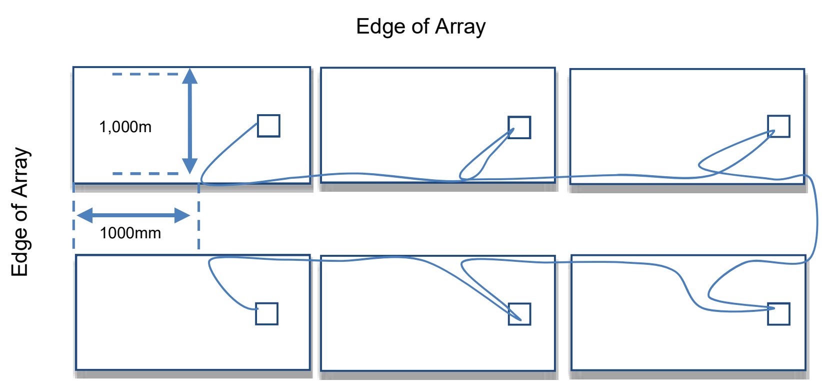


Figure 1 – Wire Management within Limited Approach Boundary

This means routing wiring internal to the array wherever possible and configuring modules, so they are positioned with junction boxes internal to the array. It is important to note that in accordance with CEC Section 64-210 that all cables shall be supported within **300 mm (6 in)** of all connectors, junction boxes, and transitions. Additionally, no conductors shall be unsupported for a length greater than **1000 mm (~3.3 ft).**

Additional consideration should be given to system voltage design and the use of MLPE as noted in *Table 1 – Energized Electrical Work Permit for Solar* Arrays in the *CoE Solar Photovoltaic Program Volume 4: Operations & Maintenance Guideline*.

3.7.5 Equipment Location & Rating

All equipment locations shall be reviewed and approved by City of Edmonton as outlined in the submission packages. The consultant is responsible for preparing drawings to illustrate placement and physical configuration of equipment (either 2D or 3D drawings). The design should stipulate that any variations from the construction documents is subject to review and approval by City staff. Existing equipment shall be included to demonstrate appropriate clearances and access is adequate to both existing and new solar photovoltaic equipment.

Equipment shall be selected to match the exposure class and rating of the existing base building equipment installed within the same space as the solar photovoltaic equipment, OR shall be as stipulated by current CEC requirements, whichever is more stringent.

4 Design Parameters

4.1 Operating System Life

Each project shall be designed for an expected service life of 30 years. All project components shall have appropriate finish to limit the effects of corrosion consistent with this expected lifetime. This expected lifetime of the DG project assumes regular maintenance and reasonably expected repair and/or replacement of some components over the life of the project. These will be further outlined in "*CoE Solar PV – Vol4 – Operations & Maintenance Guideline*", however, all components shall be designed to withstand environmental factors including solar (ultraviolet), precipitation, wind loads, snow loads, seismic loads, temperature, humidity extremes which would normally be expected to occur at the location during the service life.

4.1.1 Module Orientation

4.1.1.1 Tilt

Flat roof applications are to use a standard panel tilt (relative to the roof surface). Layouts should consider optimization of layout making use of either landscape or portrait orientation (layouts should limit to one orientation per roof/array), with the option at the discretion of the Engineer of Record and subsequent approval of the City of Edmonton, to increase or decrease the tilt angle as site specific circumstances dictate.

Table 6 - Orientation vs. Module Tilt

Module Orientation	Typical Module Tilt
Landscape	10°
Portrait	5° to 10°

Pitched roof applications, where the roof surface has a metallic finish (e.g. standing seam, corrugated, etc.), additional tilt to the already pitched roof may be applied. If the pitch of the roof exceeds 5° (≥1/12) then no additional tilt of the modules is required, and a flush mounted system shall be deployed. For other roof surfaces (e.g. shingle), they shall be flush mounted to the roof surface. In no case shall a system be mounted less than 3° when measured from the horizontal without written prior approval by the module manufacturer confirming that it will not void the module warranty.

Technical Rationale

Standing water on modules that are at a low slope (i.e. 2° or less) can contribute to Potential Induced Degradation (PID) which negatively affect production and will shorten the expected lifetime of the modules.

4.1.1.2 Height

For flush mounted installations on sloped roofs (≥ 1/12 pitch) modules should be installed with no less than **100 mm (4")** of clearance from the roof surface. For clarity purposes this measurement shall be the distance between the roof surface (not the seam height) and the underside of the module frames. Essentially the height of clearance for air movement.

On flat roof installations (< 1/12 pitch) the modules and associated wiring shall be installed at least **50 mm (2")** above the roof surface. For roofs where flow-controlled roof drains are installed and standing water is expected after major storm events, all modules and wiring shall be above the high-level line for standing water.

4.1.1.3 Azimuth

For arrays using most of the available roof space, the orientation should align with the major grid lines of the building (whichever is closer to south-facing) such that the array's azimuth is between 135° (45° East of South) and 225° (45° West of South).

For arrays using only a portion of the available roof space, and where practical, the array should utilize an East-West racking system, due-south-facing provided the bearing points can be coordinated with the underlying roof structure.

4.1.1.4 Inter-row Spacing

Module inter-row spacing is to follow a consistent "Shading Limit Angle" for all module types (e.g. 72 vs 60 cell, portrait vs landscape).

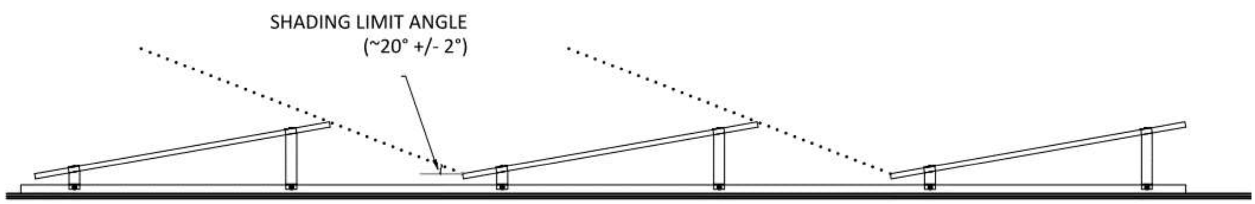


Figure 2 – Inter-Row Spacing (typical)

The shading limit angle to be used is ~20° +/- 2° depending on the racking manufacturers specifications. Shading studies shall consider the sun angles associated with December 21st to demonstrate appropriate spacing.

4.1.1.5 Shading

The array layout shall be configured to respect the no-shade window (on December 21st) for obstruction shading based on the standard shade profiles, unless otherwise specified in the contract documents:

Table 7 – Shading Considerations

Obstruction Type	No Shade Window
Elevated Roof Surfaces (exceeding **1200 mm (4 ft)** in height change)	No shade window of 4 hours – 2 hours on either side of solar noon
Roof Top Obstruction (<**1200mm (4 ft)** in height)	Apply a no-shade window of 2 hours – 1 hour on either side of solar noon.

4.1.2 DC-AC Input Ratio

DC/AC oversizing ratios should optimize the deployment of PV modules for a given roof/area, compared to the interconnection limitations and total electrical consumption of the facility – Refer to *City of Edmonton Solar Program – Volume 1: Site Selection Guideline* for details.

Standard target oversizing should be within a **120% –130%** threshold of the AC nameplate capacity (kW). Additional oversizing and input ratios may consider where site specific conditions exist:

- Matching the maximum allowable DC capacity as per the Inverter specifications (e.g. 150%) – this can specifically be of value where roof area is large, and there are limitations on system connection size.
- Minimum 100% (DC=AC) oversizing, matching the AC nameplate capacity (kW). Given the standard normal operating conditions being below the 1:1 ratio is of little value and there are likely inverter cost savings that could be considered.

In all cases, each proposed DC-AC oversizing threshold must be approved by the City of Edmonton, the Inverter manufacturer and validated by the Engineer-of-Record. Effort should be made to balance inverter DC oversizing ratios in an equal manner to ensure balanced system operation.

4.1.3 System Wiring Losses

The overall system losses must be designed to ensure an optimal system that does not sacrifice long-term performance for capital cost savings. In certain cases, capacity under the AC or DC allowance can be shifted between the two to account for system specific constraints (subject to review and approval by the City of Edmonton):

- AC Voltage Drop– Shall be in accordance with the CEC and must be designed and constructed to never exceed **2.0%** on average at Standard Test Conditions (STC). Furthermore, no AC circuit run between the interconnection point and an inverter shall exceed a **3%** maximum loss (operational related)
- DC Voltage Drop – The total DC losses should not exceed **1.0%** on average at STC across the system. Total variation between strings on the same MPPT shall be designed for no greater than **+/- 0.5%** from the other strings connected to the same MPPT. This specification must be met for all strings, DC combiner boxes, home run cable, and other DC components in the DC path. Module whips are to be included in all of the loss calculations.

In all cases in either the AC or DC systems, the design shall maximize cable management efficiency and minimize lengths in order to provide the most efficient system possible. For unique inverter configurations (i.e. remote from the array, or where optimizers are used) a different mix between AC and DC average losses can be provided as long as the end-to-end total does not exceed a total of **3%** on average.

4.1.4 String Design

DC homerun string lengths shall be consistent per MPPT and sized such that:

- The voltage remains within the allowable range per the inverter specifications at the minimum operating module temperature calculated as per rule CEC Rule 64-202 based on the specific location.
- Minimum string lengths remain within the inverter specification for MPPT voltage range at 60 ^{o}C.
- Over the course of the system operation, degradation/aging does not reduce operating voltages sufficiently during the summer months (e.g. at year 30) to be below that of the inverter minimum MPPT window.
- They are arranged to minimize home-run wire lengths and in a regular and symmetrical manner with attention to constructability and maintainability.
- Minimize the amount of inter-row/sub-array jumpers for strings.
- Validated by the inverter manufacturer to be in accordance with its warrantee conditions.
- Positive and negative runs are co-located to minimize open loops of wiring.
- All strings are labeled at either end of the run (e.g. where it connects to the modules and to the combiner or inverter).

4.1.5 Means of Isolation

The system shall be designed to ensure that all components of the system can be isolated in accordance with CSA Z462 to permit the servicing of units in a safe and cost-effective way. For clarity on the DC side of the system where modules are always energized quick connects (e.g. Multi-contact MC4, Amphenol UTX, or equivalent) shall be provided integral to (for inverters that have bulkhead connectors) or immediately adjacent to – e.g. within **1500 mm (5ft)** wire distance – for inverters with wired terminals to permit safe removal and replacement of inverter, components or

Technical Rationale

Quick connects physically adjacent to all combiners and inverters ensures that equipment can be serviced and replaced in a safe and reasonable manner in accordance with the intent of CSA Z462. It is more time consuming, and expensive to try and isolate DC strings within the array to service the equipment.

associated equipment without isolating strings within the array. Relying on module whips within the array as the only means of isolating the inverters will not be accepted.

5 Design Considerations

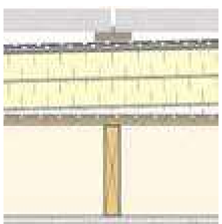
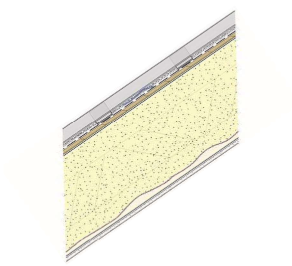
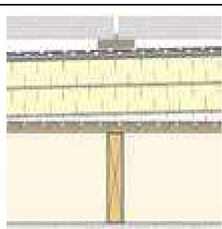
5.1 Roofing Type / Compatibility

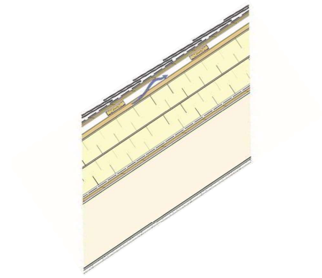
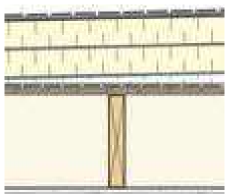
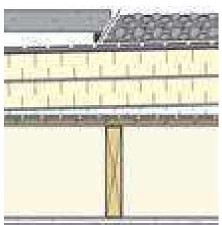
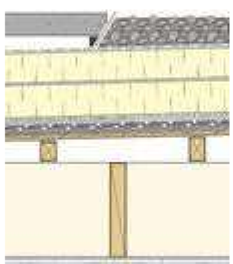
5.1.1 Roof Protection (shims, sacrificial membrane, and/or drain mat)

If required by the roofing manufacturer warranty provisions, a sacrificial layer and/or the appropriate roof protection shall be installed prior to the installation of any equipment (including racking, modules, and rooftop mounted equipment).

The following table contains common roof assemblies that may be found at the sites selected to receive PV equipment. It should be noted that the graphics show combustible construction (wood-frame), however the membrane requirements for non-combustible construction (steel and concrete structure) will be similar.

Table 8 - Roof Type vs Protection Requirements

Assemblies	System	Material Type	Solar PV Compatibility	Roof Protection Material	Sacrificial Layer Thickness (mm)	Notes
	Built-Up Roofing System	Asphaltic products, tar, torch applied	High	Pavers on rubber pads or pedestals	**Min 6 mm (1/4")**	Confirm rigid insulation type prior to installation. Replacement of localized sections of insulation may be required.
	Metal Panel (roll formed)	Steel, Galvalume, Aluminum, Copper etc.	High	Rubber pads	**Min 6 mm (1/4")**	If drilling anchors through the standing seams, ensure all holes are sealed with sealant
	Polymer Modified Bitumen (Mod-Bit)	SBS polymer-hot mopped or cold applied APP polymer-torch applied / heat welded.	High	Pavers on rubber pads or pedestals	**Min 6 mm (1/4")**	Confirm rigid insulation type prior to installation. Replacement of localized sections of insulation may be required.

	Shingles	Asphalt, Fiberglass, Cedar etc.	Medium	SBS Cap Sheet (Inverted)	**Min 5 mm (3/16")**	Ensure L-foot bracket is equipped with an integrated flashing and elevated bolt hole; install continuous sealant along the tops and sides of securement bracket
	Single Ply Membranes – Mechanically Fastened	TPO PVC	Medium	Type 4 XPS or Rubber Pads	**25 mm (1")**	Confirm rigid insulation type prior to installation. Replacement of localized sections of insulation may be required.
	Single Ply Ballasted Membranes	EPDM	Medium	Type 4 XPS or Rubber Pads	**25 mm (1")**	Confirm rigid insulation type prior to installation. Replacement of localized sections of insulation may be required.
	Inverted Roof Assembly (Incl. Ballasted Systems, Decks, and Greenroofs)	Asphaltic products, tar, torch applied, hot-applied rubberized asphalt	High	Pavers on rubber pads or pedestals	**Min 6 mm (1/4")**	Confirm rigid insulation type prior to installation. Replacement of localized sections of insulation may be required.
		SBS polymer-hot mopped or cold applied APP polymer-torch applied / heat welded.	High			
		TPO PVC	Medium			
		EPDM	Medium			

Where applicable, ballast (river rock, pea pebble, etc.) on the roof membrane must be cleared before placement of the racking. Any ballast to remain trapped between the racking substrate and the roof membrane poses a puncture or abrasion hazard. The ballast must then be restored only up to the edges of the racking. Where required and specified by the Structural Engineer, ballast (river rock, pea pebble, etc.) shall be removed from the roof, respecting the conditions of the Roofing Manufacturer (e.g. ARCA).

5.1.2 Provisions for Temporary Roof Protection (during installation)

An additional rooftop staging plan must be provided for the roof loading and roof protection strategy during construction for material and products being staged on the roof (e.g. module skids) during installation. The locations and structural capacity for short term staging approved by the structural engineer-of-record shall be indicated on the roof plan.

5.1.3 Allowances for Roof Servicing (e.g. equipment location, removability)

Where seams exist within the roofing, the design of the racking and string (where possible) shall permit the removal of sub-sections of the array to facilitate servicing and maintenance activities without requiring the entire system to be locked out. This means creating sub arrays that are electrically and mechanically independent where practicable. Where wind loading requirements necessitate additional mechanical interconnections, those points of connection between sub-arrays shall be designed so that they can be safely removed to facilitate servicing.

5.1.4 Roofing Penetrations

Roof penetrations should be avoided where possible; however, if required, the following sketches should be referenced for methods and requirements on the specific roof membrane/type. The critical concept for any roof penetration is to ensure upon passing through the conduit, all layers are re-sealed to re-establish continuity of that particular roof assembly component. For example, fully seal the conduit to the vapour retarder, the thermal layer (insulation), air barrier, and the waterproofing layer. Final consideration should be made by the existing roof warranty and recommendations or mandated work that must be performed by the roofing manufacturer/supplier to maintain the warranty.

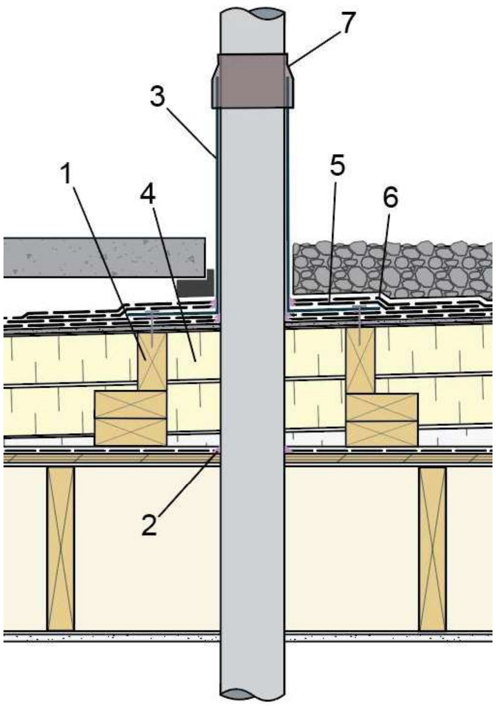


Figure 3 - Flat Roof Penetration (Conventional)

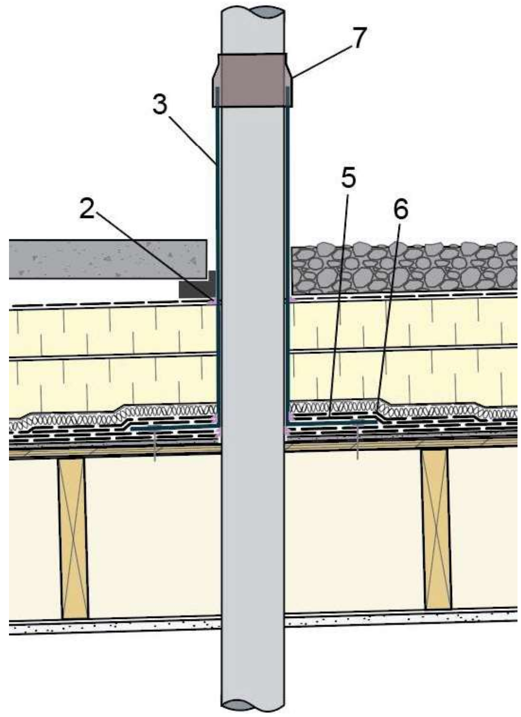


Figure 4 - Flat Roof Penetration (Inverted)

1. Construct wood blocking to support conduit penetration stack flange (conventional).
2. Apply heal bead of sealant at joint between air/vapour barrier and penetration.
3. Mechanically fasten aluminum welded conduit penetration stack per membrane manufacturer requirements and ARCA standards. Stack to extend a minimum of **200 mm (8 in**) above finished roof surface.
4. Re-install rigid insulation tight between wood blocking and penetration (conventional).
5. Apply primary torch-on SBS membrane patch over plumbing stack per membrane manufacturer requirements and ARCA standards.
6. Apply secondary torch-on SBS membrane patch over primary patch per membrane manufacturer requirements and ARCA standards.
7. Install heat-shrink collar per conduit manufacturer installation instructions.

By introducing a new conduit through an existing roof assembly, thermal bridging is potentially being introduced. Presuming the new conduits will be made of metal, they will have relatively low thermal resistance and form a continuous path through which heat is lost. Given the relatively low thermal resistance of the new conduits compared to the surrounding roof assembly, heat loss and frost formation on the conduit within the building during the winter months is a possibility. Minimizing the number of conduits penetrating the roof assembly and locating the conduit penetrations in sufficiently heated and less-humid locations should be considered. Careful planning and consideration to the quantity and location of the conduits is required. To reduce condensation issues, exterior rated duct seal (or equivalent) should be installed at both ends of any conduit entering/exiting an exterior wall/roof, sealing around conductors after installation.

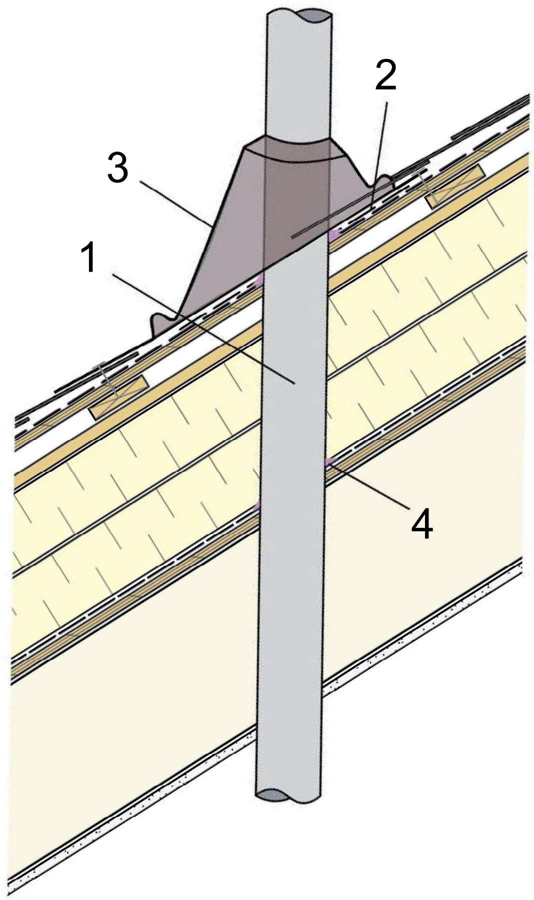


Figure 5 - Pitched Roof Penetration (Shingles)

1. Ensure insulation is returned to normal thicknesses around conduit penetration and seal penetration at air/vapour barrier with continuous sealant or tape
2. Install continuous high-temperature self-adhered membrane to water shedding layer (underlay)
3. Install flexible rubber pipe gasket and fully seal in accordance with manufacturer installation instructions.
4. Seal air/vapour barrier around penetration.

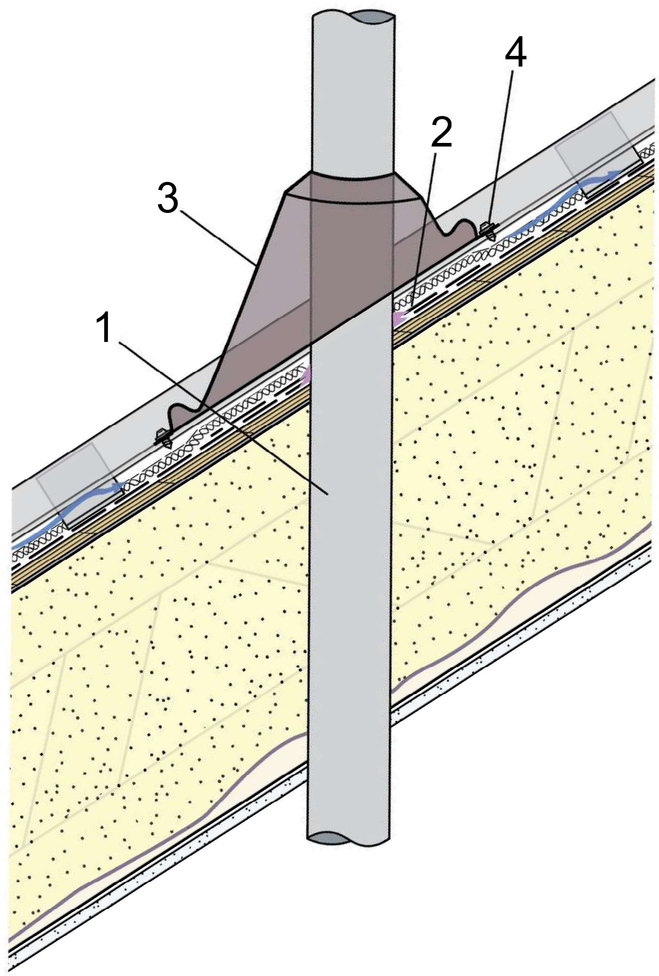


Figure 6 - Pitched Roof Penetration (Metal Panels)

1. Ensure insulation is returned to normal thicknesses around conduit penetration and seal penetration at air/vapour barrier with continuous sealant or tape
2. Install continuous high-temperature self-adhered membrane to water shedding layer (underlay)
3. Install flexible rubber pipe gasket and fully seal in accordance with manufacturer installation instructions.
4. Fully seal all screw penetrations with silicone sealant.

5.2 Racking System

Racking systems will vary based on the selected manufacturer and deployment strategy (e.g. rail based, ballasted, east-west etc.) however both the manufacturers and roof protection prescribed requirements need to be followed to ensure the existing roof condition is not negatively impacted.

5.2.1 Ballasted (Non-Penetrating) Systems

Ballasted systems are to be the primary solution for all flat roof applications to avoid roof penetrations. Corner clamped systems will not be permitted due to the risk to modules caused by the high accumulation of snow on roofs located within the City of Edmonton.

Figure 7 - Ballasted Racking Solution

Ballasted racking systems typically require a sacrificial mat to be placed underneath each ballast location, as shown above, however, refer to table 8 for thickness requirements on specific roof types where an additional sacrificial membrane needs to be included.

5.2.2 Clamping Systems

Clamping systems are to be used for metallic roof surfaces (e.g. standing seam metal). The clamping method needs to match the seam profile. Special structural considerations should be given to standing seam or corrugated metal roofs if relying on the metallic roof to support the solar array. Pull out strength, and density of the metal roofing fasteners shall be reviewed to ensure they can withstand the uplift loads imposed on the roofing.

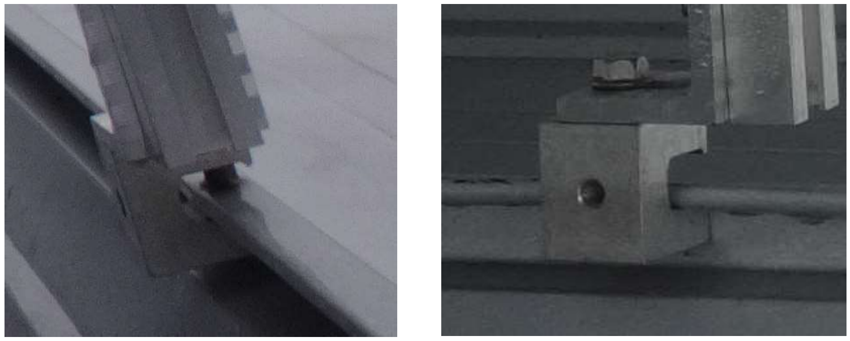


Figure 8 - Metallic Standing Seam Roof Clamps

The material type (copper, aluminum, steel) and profile must be considered when selecting a clamp type to ensure compatibility and avoid corrosion. Typically, 24 gauge or heavier standing seam metal roofs are required to accommodate a metallic clamping type racking connection

Further, some standing seam metal roofs may be supported intermittently by clips and require free movement along the clips for thermal expansion. Special consideration of clamp locations should be made to avoid restricting thermal expansion of the standing seam metal panels along their supporting structural clips.

5.2.3 Anchored Systems (e.g. penetrating)

Anchored systems are required for primarily non-metallic (e.g. shingle) pitched roofs (>1:12). Each penetration must be equipped with the appropriate flashing, and properly weatherproofed, leaving the roof in the same functional condition as it was prior to installation. Fasteners used to anchor the system to the structure below shall be sized to ensure the load carrying capacity of the existing member is not compromised. Figure 9 provided below is to be referenced when anchoring is required on the racking system.

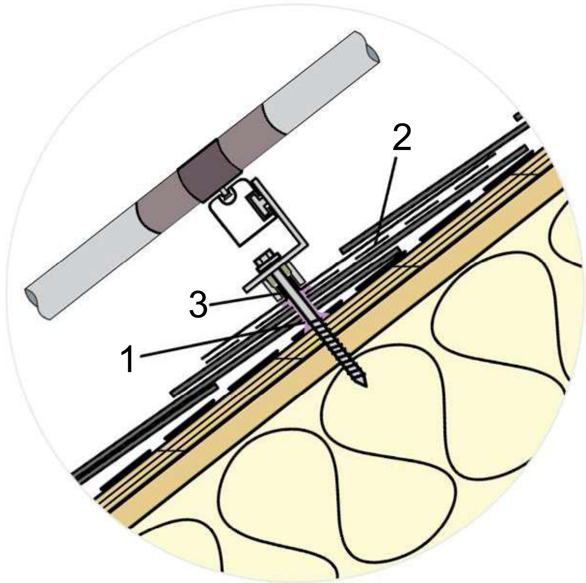


Figure 9 - Shingled Roof - Racking Penetrations

1. Fill bolt pilot hole with sealant and install continuous sealant along top and sides of mounting brackets
2. Install sacrificial layer of SBS cap sheet, inverted so granules are facing down
3. Ensure bolt hole is equipped with factory-installed raised flute.

5.2.4 New Construction Considerations

When considering roof assemblies for new construction projects, initial and upfront costs typically are the primary motivators for membrane and assembly type selection. It is important to consider the long-term costs of the roof assembly, such as life cycle renewal periods, maintenance requirements, and overall durability. Since PV systems require regular maintenance, that typically means additional staff or trades dedicated to the maintenance of PV systems will also be accessing the roof. This will be in addition to the typical roofing trades, mechanical and electrical trades conducting routine maintenance.

5.2.5 Roof Type Selection

Due to the added maintenance staff traffic and the potentially increased costs for the removal and reinstallation of the PV system during end-of-lifecycle roof renewals, a longer-lasting and more-durable roof system is recommended. Currently, the roof membrane system that could provide longer-lasting lifecycles and more durability is a 2-ply modified bitumen membrane system. However, each major manufacturer provides several “grades” or “lines” of modified bitumen membranes and when possible, selecting the “heavy duty” line of modified bitumen membranes is recommended. Most major modified bitumen membrane manufacturers will also provide higher-reflecting capsheets and grades of modified bitumen membranes suited for solar photovoltaic applications.

When a modified bitumen membrane roof system includes the “heavy duty” line and is properly maintained over its lifecycle, a catalyzed resin membrane system may be installed (prior to installation of the solar project) to prolong the service life of the roof. If properly maintained and no major water ingress issues have occurred, specific membrane manufacturers can provide a retrofit overcoating system consisting of a catalyzed resin membrane that may prolong the service life of the roof by an additional 10 years. It should be noted this catalyzed resin membrane overcoating system is typically only compatible with modified bitumen membrane systems.

5.2.6 Roof Insulation Selection

Since ballasted systems are the preferred method of incorporating PV systems for the City of Edmonton, there will be additional weight placed directly on the roof assembly. This introduces numerous point loads of several kilograms of weight at concentrated points. It is critical to ensure the rigid insulation within the roof assembly, whether it is conventionally insulated or inverted, has the capacity to withstand the localized point loads of the PV system.

In new construction, properties of the proposed rigid insulation must be carefully reviewed and confirmed prior to installation. Confirming compressive strength properties via technical data sheets is a common way to confirm if a proposed rigid insulation is suitable to withstand the localized point loads imposed by PV systems.

In existing assemblies, exploratory openings, through to the structural deck, should therefore be incorporated into the design process of any building anticipated to receive a new PV system. If the existing rigid insulation is not capable of withstanding the localized point loads imposed by the new PV system, it is possible to replace localized areas of rigid insulation with high-compressive strength rigid insulation. Upon reinstallation, compliance to manufacturer written instructions and local roofing association application standards is required.

5.2.7 Provisions for Servicing

If the required setbacks mandated by the ARCA and membrane manufacturer are maintained, access to roofing components requiring servicing (maintenance) is readily provided. However, if the required setbacks are not maintained, removal of panels or sometimes entire racks may be necessary. If this is the case, this will add cost to the overall maintenance of the roof system in question. Where possible this situation should be avoided, however it may be necessary on a case-by-case basis.

5.2.8 Roofing Warranties

5.2.8.1 Manufacturer Warranties

Most roofing manufacturers have similar requirements with respect to incorporating external, complimentary systems to their products, such as pedestrian surfaces, green roof assemblies, and PV systems. It would be prudent to review all manufacturer requirements either through their product literature or speaking directly with a technical representative, prior to finalizing the design of a new PV system on a new or existing building.

5.2.8.2 Alberta Roofing Contractor Association (ARCA)

ARCA was established in 1961 by Calgary and Edmonton roofing contractors to develop standards for roofing product applications for the betterment of Alberta’s roofing industry. ARCA also provides all-inclusive warranty packages ranging from 5 to 10 to 15-year durations. In order for a roof to qualify for an ARCA Warranty Certificate, the roof assembly must be on the ARCA’s approved product list, be installed by an ARCA member in good standing, and have the installation reviewed and reported on by an ARCA-Accepted Inspector. All incidents of water ingress are addressed by ARCA and its member roofing contractors at no additional cost to the building Owner.

Various requirements pertaining to PV systems are found under “Roof Mounted Photovoltaic Equipment” within each main section of the ARCA Roofing Application Standards Manual. There are also several technical bulletins that supplement the requirements outlined in the standards manual. This information can be found on-line at ARCA’s website at https://www.arcaonline.ca/.

Careful review of these requirements is recommended prior to finalizing the design and layout of the new PV system. For the City of Edmonton projects, it is anticipated that the anchoring method (i.e. ballasted) and the row spacing (optimized to maximize array density while minimizing inter-row shading) will vary from the standard ARCA requirements. As such, it is recommended a dialogue be established with the ARCA Technical Officer, preferably from the early stages of design. Where a satisfactory technical solution cannot be settled upon, it may be necessary to explore an alternate means of maintaining the roof warranty (e.g. working directly with the manufacturer etc.).

5.2.9 Conductors & Conduits

5.2.9.1 Protection of roofing for support on/above roof

Running conduits from PV systems across roof areas to other areas of the building containing inverters and other equipment associated with the PV system are common. In order to protect the longevity and durability of the roof membrane, it is not recommended to fasten the conduit directly through roof membrane. Instead, incorporate the use of pre-manufactured roof blocks at regular intervals. These rubber blocks are usually soft enough to minimize damage to the existing membrane, however if additional protection is required (as stipulated by the roofing system manufacturer), setting each block on an additional layer of **25 mm (1")** thick layer of Type 4 XPS insulation is recommended.

5.2.9.2 Flashing

Inevitably, conduits may have to penetrate the building enclosure to facilitate the electrical interconnection. Opportunities to utilize side-wall penetrations should be identified including the use of flashed "doghouses". If the only option is a roof penetration, then attention should be paid to the placement and detail of the penetration. Most roof membrane manufacturers have purpose-designed penetration boots or they will have recommended accessory manufacturers that comply with their installation and application standards. Care should be taken when considering which penetration boot to use as different roof membranes require different types of penetration boots. It is recommended to contact the applicable roofing manufacturer technical representative during the design stage to ensure the correct roofing hardware is utilized to maintain the existing roofing warranty and maintenance plan.

5.2.10 Placement of Roof Penetrations/Anchors

Specific penetration and/or anchor locations are to be specified by the equipment manufacturer on the proposed layout and approved by the City of Edmonton. Where an ARCA Warranty Certificate has been applied for, observing the setback requirements outlined by the ARCA is required. If minimum setback requirements cannot be maintained, the ARCA Technical Officer should be contacted immediately for review and approval.

5.2.11 Routing of Conductors over Parapets

All conductors where they cross parapets shall be fully supported on prefabricated products such that the conductors, cable tray or wire-way do not make contact with the parapet during installation and during the lifetime of the system. Provide a cable tray to fully support the conductors where they cross the parapet, and design for proper "waterfall" sections of cable tray (refer to Figure 10) to make the transition from the horizontal to the vertical raceway.

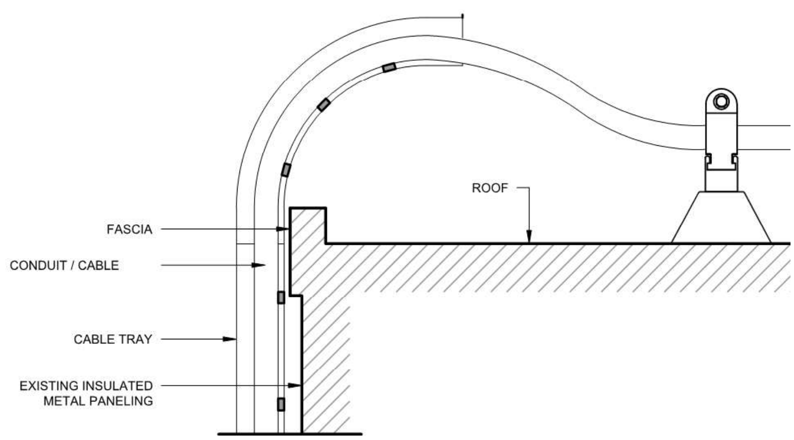


Figure 10 - Waterfall Style Transition Over Roof Edge

Conductors shall be fully anchored as close to the edge of the parapet as possible and at the top of the vertical face to ensure the spacing is maintained. All anchors shall be positioned so that no flashing or other weatherproofing barrier is compromised. All penetrations into the wall surface must be properly weatherproofed, leaving the wall in the same functional condition as it was prior to installation, and shall not be made into the parapet flashing as that forms part of the weatherproofing barrier.

All cable trays must be fully clad with flashing that wraps the entire cable tray (front and back) and is anchored flush to the wall surface. This is to ensure that conductors cannot be accessed, and the ladder tray cannot be used to access roof areas.

5.2.12 Wall Penetrations

All penetration locations must have written approval from the City of Edmonton and/or building operator. All building penetrations shall be appropriate and compatible with the type of cladding and/or exterior wall system of the building enclosure. Consideration for determining whether a cladding type is appropriate is outlined in Section 3.4.6.2

All penetrations must be properly weatherproofed, re-establishing the air, vapour, water and thermal control layers that are present in the wall assembly. All penetrations must also incorporate all fire stopping systems as mandated by the Alberta Building Code, and NFPA Code and enforced by Authorities Having Jurisdiction.

Similar to roof penetrations, introducing a new conduit through an existing wall assembly may introduce unwanted thermal bridging. Heat loss and frost formation on the conduit within the building during the winter months is a possibility. To reduce condensation issues, exterior rated duct seal (or equivalent) should be installed at both ends of any conduit entering/exiting an exterior wall/roof, sealing around conductors after installation, as close to the penetration as possible (adjacent elbow or equipment), minimizing the number of conduits penetrating the wall assembly and locating the conduit penetrations in sufficiently heated and less-humid locations should be considered. Careful planning and consideration to the quantity and location of the conduits is required. Consider where appropriate using non-metallic conduit for the portion of conduit that transitions the thermal control layer.

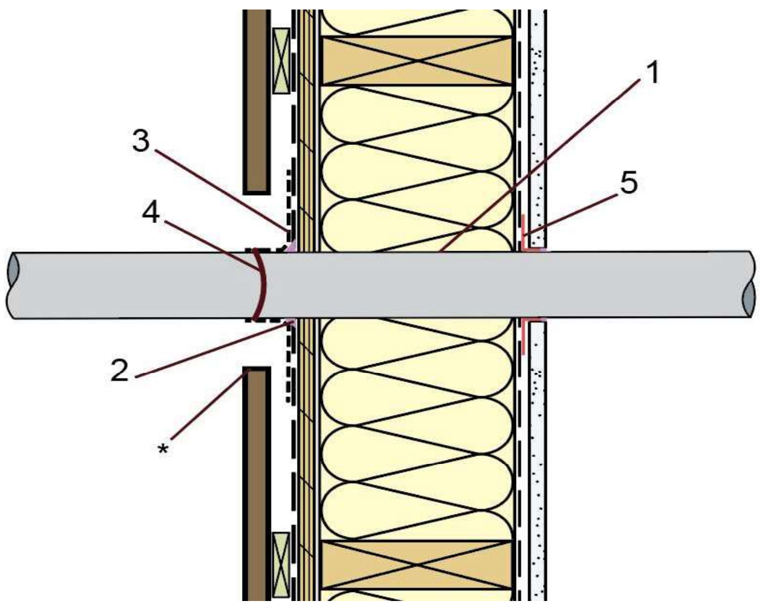


Figure 11 - Standard Wall Penetration Detail

1. Fill section of conduit that passes through the wall with fire stop putty
2. Ensure conduit penetration is fully sealed at water shedding layer
3. Install self-adhered membrane patch around and onto penetration
4. Terminate self-adhered membrane patch with clamp collar
5. Ensure air/vapour barrier is continuously sealed with tape or similar

*Cladding around penetration not shown for clarity

5.3 Equipment Enclosures

5.3.1 NEMA Ratings & Requirement

All equipment shall comply with the following ratings by location. Variations from this criterion will be considered on a case-by-case basis. Design teams shall provide rationale for a substitution:

Table 9 - NEMA Ratings by Location

Location	NEMA Rating	Accessories
Indoor – non-sprinklered Room	NEMA 1	Not Applicable
Indoor – sprinklered room	NEMA 1 / NEMA 3R	Sprinkler Shield / Drain
Outdoor Wall Mounted (vertical)	NEMA 3R	Drain
Outdoor Roof Mounted (sloped or flat)	NEMA 4	Breather & drain

A drain or combination breather & drain (that is NEMA 4 rated to preserve the enclosure rating) shall be installed on all balance of system equipment (e.g. junction boxes, combiner boxes etc.).Where connections within the enclosure are exterior rated an alternate configuration maybe acceptable subject to approval by the City of Edmonton.

5.3.2 Exposure

All equipment shall be positioned such that upper roofs do not drain or shed water, snow, or ice onto equipment below. Where that condition is unavoidable (e.g. due to site specific constraints), the design shall include for a covering/awning overtop of the equipment (regardless of its NEMA rating). The awning shall be deep enough to permit service personnel to access and open the equipment without having ice and water enter the devices.

Inverters and AC Combiner panels shall be mounted on east or north wall surfaces to minimize the risk of overheating and compromise to system performance. Where mounting equipment on roof surfaces or walls with south and west exposures cannot be avoided, shade covers shall be installed to prevent direct solar irradiance from contacting the equipment enclosures. All shading devices shall be approved for use by the inverter manufacturer to ensure they do not detrimentally impact air movement or required clearances.

Technical Rationale

Overheating inverters can cause the inverter to derate and reduce total output. Similarly, AC breakers that run at elevated temperatures can result in nuisance tripping, increasing the need for service calls and detrimentally impacting solar generation.

5.3.3 Colour Coding

All electrical equipment to be colour coded as indicated within the *Consultant Manual Vol2 – 2019 v4.0_Technical Guidelines Appendix A – Table A-2*:

All pull boxes, junction boxes, covers, and conduit fittings shall be enamel finished in the colour indicated in Table A-2. All cover markings to be in black lettering or as mandated by the CEC associated DC or AC level warning labels (as required by the AHJ) shall be in red with white letters.

All switchgear, distribution centers, panelboards, motor control centers, motor starter cabinets, motor control cabinets, disconnect switches, contactor cabinets, relay cabinets, transformers, termination cabinets, splitter boxes, bus duct, cable duct, etc. are to be colour coded as indicated in Table A-2.

5.4 Racking

5.4.1 Racking Type Considerations

Racking systems components in contact with modules shall be aluminum or be installed to prevent galvanic corrosion. It is acceptable for main structural members to be galvanized steel, provided they are galvanized after any manipulation of the underlying substrate has been completed. Polymer based racking solutions are not acceptable to the City of Edmonton.

5.4.2 Module Installation

Modules are to be installed in accordance with clamping requirements specified within the racking and module manufacturer's installation manuals. Corner clamping of modules will not be permitted. Racking systems shall ensure modules are fully supported with a rail-based system.

5.4.3 Wire Management

Wire management within the array shall be considered when selecting the racking system. Where a specific east-west framing member cannot be reached with module whips, some means of supporting the wires will be required. Any metallic support or wireway shall be integrated into the racking bonding strategy.

Design drawings shall include wire management requirements. RPVU90 conductors and module whips shall maintain a bend radius of no less than **100 mm (4")** when exiting the junction box, or when routing conductors within the array. 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 DC system.

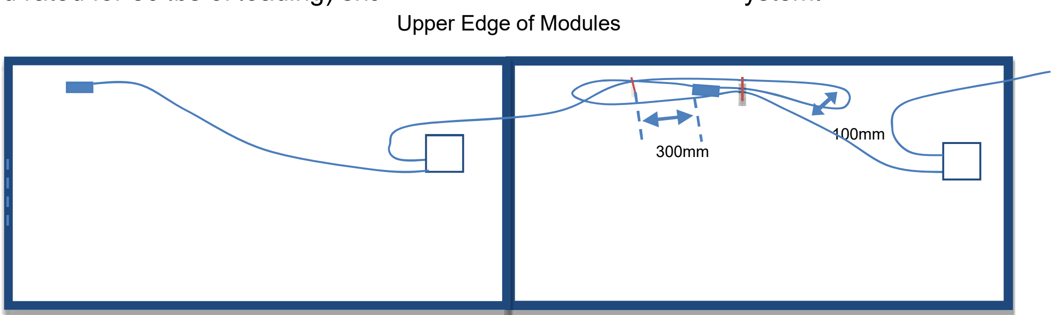


Figure 12 – Wire Management Considerations

Where stainless steel module conductor clips are used, attention should be paid to ensure that the thermal expansion and contraction of wiring does not cause undue wear on the jacket. It is important to note that in accordance with CEC Section 64-210 that all cables shall be supported within a maximum of **300 mm (6")** of all connectors, junction boxes, and transitions.

Inter-row jumpers shall be configured so that the quick connectors (e.g. Multi-Contact MC4, Amphenol UTX or equivalent) are supported up above the roof surface at least **150 mm (6").** Where rigid PVC conduit is used to mechanically protect inter-row jumpers, all conduits shall have end bell (or rolled edge) to prevent wear on conductors, or all conductors shall be protected by UV rated split loom.

5.4.4 Array Layout / Ballast Plan

Module layouts and subsequent ballast plans are to be completed and approved prior to finalizing the Issued for Construction package. Permit applications (including design package) shall include the City of Edmonton approved ballast plan and finalized module layouts.

5.5 Wiring – General

5.5.1 Connections

All connections shall be made in accordance with manufacturers requirements. Where lugs are provided within equipment, notation shall be included in all documents for installers to torque field terminations and mark with a red torque line and to torque check factory connections. Where an option exists, preference shall be given to connections made using irreversible hydraulically crimped connections made with a crimper and specific die set (universal crimpers are not acceptable). Those crimped terminations shall be bolted with suitably rated hardware (e.g. grade 8 or equivalent for electrical connections).

Where conductors of different sizes are being stepped down (e.g. to minimize losses, but still respect termination size), connections inside equipment can be made with an insulated splice block (e.g. Nimbus or equivalent for two conductors being reduced to a single conductor, otherwise irreversible compression pin reducers shall be used). Ensure that all connections can be safely torqued and there is enough space to properly service.

5.5.2 Cable Supports

All cable installed horizontally on roof or vertically on building wall are to be secured to strut channel, such as Unistrut, with metallic clamps, not tie wraps. Supports shall be spaced such that the cables cannot sag and drop closer than **100 mm (4")** from the roof surface.

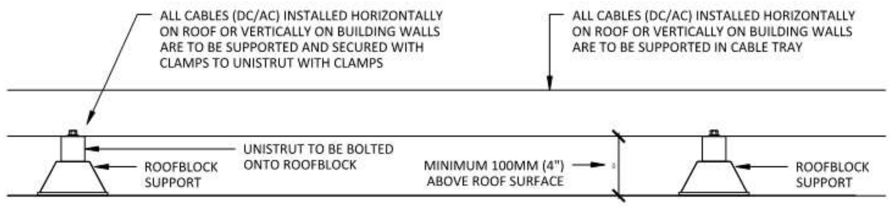


Figure 13 - Conduit/Cable Support (Typical)

5.5.3 Cable Tray

All rooftop conductors that are more than 1 m outside of the array throughout their length must be installed within cable tray. Attention shall be paid to the wire sizing to ensure that temperature derating does not reduce the ampacity of the cables below design conditions. If any spacing is assumed (e.g.,100% of cable diameter), the specific spacing and configuration shall be detailed within the design package.

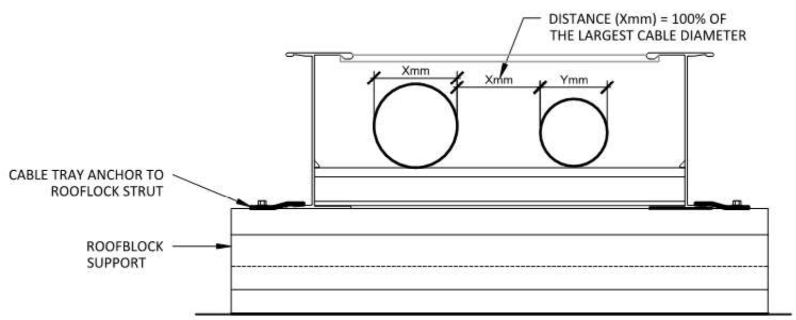


Figure 14 – Cable Tray Support (Typical)

All cable tray hardware shall be stainless steel, and all integral bonding systems shall be installed as per the cable tray manufacturers requirements.

5.5.4 Metallic Liquid Tight

All DC conductors that exit the array (i.e. to enter the inverter, combiner box, or raceway) shall be installed within metallic liquid tight conduit that is properly supported at the array edge, along its length and at its point of termination.

5.5.5 Trenching

Any trenching of cables must be done in accordance with *"EPCOR Design and Construction Standards Volume 7"*, applicable by-laws and building codes. Proper base fill, depth and backfill must be used, with the disturbed surface returned to as close to the original condition as is reasonably possible in accordance with CEC2018 Diagrams D8 to D11.

A separate, empty conduit (at least **53 mm (2")** or the same size as the largest conduit installed whichever is larger) shall be placed in the trench for future cabling needs. The conduits shall be brought to grade with a pull rope and each end shall be sealed with polyurethane or similar. Rigid PVC conduit of a suitable thickness/gauge shall be used for all below-grade conduit. All trenched cables (and electrical conduits) shall be buried with appropriately placed red or yellow traceable warning tape. At each point that a cable trench changes direction, an access well shall be installed.

5.5.6 Rodent Protection

Flush mount systems integrating module level DC arc fault equipment (e.g. DC optimizers, AC Micro-Inverters) are to include additional means of mechanical protection around the perimeter of each sub array to prevent against rodents. This mechanical protection should be in the form of PVC coated galvanized wire mesh (i.e. Critter Guard), utilizing J-hooks to secure the mesh to the racking/modules.

Figure 15 – Wire Mesh for Rodent Protection

This form of mechanical protection is not acceptable for <u>fixed tilt (ballasted)</u> systems, as adequate attachments do not satisfy the protection requirement and increase the loading of the racking systems (e.g. clamped, ballasted etc.) beyond the specifications of the racking.

For fixed tilt systems where DC arc fault equipment is not located at the module, the City of Edmonton must approve the final layout to ensure no sub-arrays or sections of array are subject to increased risk of damage from rodents.

5.6 DC Wiring

5.6.1 Wire Protection

All DC wire shall be installed in such a way as to protect it from direct exposure to UV. This includes routing conductors behind the modules, ensuring wire ways and cable conveyance systems have covers. Any wires with more than 50mm (2") of exposure shall have a UV rated split loom installed to protect it. An effort shall be made within the design to minimize lengths of exposed wire, and where it is unavoidable – define the specific means of protecting conductors (e.g. inter-row jumpers etc.).

> **Technical Rationale**
>
> UV ratings for RPVU wire are a measure for UV resistance, not a claim of UV proof. All wiring exposed to direct sunlight will age and may need to be replaced before the service life of the system is reached. Specific attention should be paid to wiring that is not black as methods for ensuring UV resistance are not as stable in coloured cables.

5.6.2 Maximum System Voltage

The maximum system voltage limits shall be adhered too based on system location and type:

Table 10 - Maximum DC System Voltage

Project Type	Maximum Voltage
Residential Buildings	600 VDC
Commercial Buildings	1500 VDC
Ground Mounted Arrays	1500 VDC

5.6.3 Photovoltaic Source Circuit (a.k.a. String Wiring)

All string wiring shall be Copper (Cu) and shall be sized no less than #10 AWG. Larger sizes shall be considered where the loss calculations require it, but wiring shall not be larger than #8 AWG. If larger conductors are required to minimize voltage drop the circuit design should be reconsidered. Designers shall consider using multi-conductor TECK90 cable for remote inverter runs (at grade, inside, etc). Associated conduit for the DC circuits shall meet all CEC requirements, regarding the route and location of the DC conductors (at grade, indoors, etc).

5.6.4 Photovoltaic Output Circuit (a.k.a. Home Run Cables for external combiners)

Where external combiners (either rapid shutdown and/or arc fault interrupt) are used; the conductors between the combiner and the inverter shall be Copper (Cu) and shall not exceed the maximum size/rating of the available terminals within the inverter (or combiner). On a case-by-case basis (subject to approval by the City of Edmonton).

5.6.5 Array Bonding Methods (e.g. DC bonding and components)

All racking, supports, raceways, and other metallic systems shall be Approved in accordance with UL2703 certification for bonding systems. Compliance shall be in accordance with the CEC Section 64-222 and clarified in *Standata Electrical Safety Information Bulletin 18-CECI-64.* This system shall ensure it considers the specific module specified. The array at the designated number of bonding points (as detailed in the UL approval) shall be connected to the bonding wire (or grid), either directly with exterior rated lugs, or indirectly using an approved grounding system (e.g. WEEB or equivalent). All bonding/grounding connections shall be made to ensure they make contact through the anodized frame or racking component.

Module grounding lugs shall be made from tin plated solid high strength copper UL listed for direct burial exterior exposure. All associated hardware (including lug set screw) shall be stainless steel - the following lugs will be acceptable as alternates to a WEEB rated lug:

- ILSCO SGB-4
- ILSCO GBL4 DBT
- BURNDY CL50-1TN
- NSI GLC-4 DBP

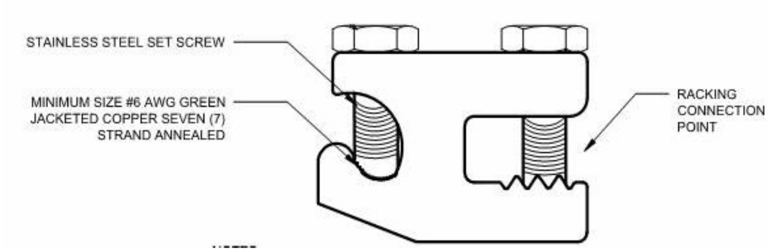


Figure 16 - Bonding/Grounding Lug Detail

Any alternative lugs proposed for use in the system shall be submitted for review and approval by the City of Edmonton prior to procurement or use on the site. All module frames, panel/array support structures, metal enclosures, panel boards and the inverter equipment shall be bonded to a common bonding conductor. This conductor is to be coordinated with the AC bonding conductor (See AC Bonding/Grounding Section for more details).

All dissimilar metal connections shall be protected from galvanic corrosion through the use of stainless-steel hardware. Only exterior rated bond lugs, ring terminals etc. should be used within arrays or in exposed locations.

All copper bonding conductors shall have a jacket where they enter the inverter and/or combiner box, or otherwise be protected where they contact dissimilar metals (e.g. racking system). Bond conductors resting on aluminum cable tray, roofing, or racking shall have a green jacket to prevent galvanic corrosion. All connection points between dissimilar metals should be coated with antioxidant paste.

In a grounded transformer-based system the connection between the negative (or positive) and ground is typically within the inverter (and forms part of the Ground Fault Interrupt (GFI) system). Unless specifically required by the inverter manufacturer, do not ground the negative (or positive) conductor at any other point, as this could compromise the operation of the GFI system.

5.6.6 DC String Field Terminations

All DC string terminations are to be made using CSA approved quick connect product (e.g. Multi-Contact MC4, EVO2, Amphenol UTX or equivalent). All terminations are to be made using CSA approved crimping tool designed specifically for the connector; universal crimpers are unacceptable. Where possible avoid the use of any screw terminations for DC strings – select spring loaded breakers, and terminal blocks where practicable. Quick connect terminations shall be a certified and tested mated pair (MC4-MC4, Amphenol-Amphenol, etc.) and shall not have connectors from different manufacturers in the same connection. Preference is for a single type of connector per site to simplify operations and maintenance activities.

5.7 Inverter

5.7.1 DC Isolation

All string inverters are to be equipped with an integral load break rated DC disconnect. Where multiple DC disconnects exist within a single inverter signage should be included on the inverter notifying service personnel that there are multiple points of isolation required.

In addition to the load break rated disconnect switch, all string wiring shall be equipped with MC4 (or equivalent) connections either immediately at the inverter (in the case of inverters with integral quick connect bulk head connectors) or within **1500 mm (5 ft)** of the inverter on the string wire and protected from the elements.

5.7.2 AC Isolation (e.g. isolation device location)

Whenever AC disconnect(s) are required for roof mounted inverters (due to location relative to AC panel/combiner) the AC disconnect shall be mounted, as practical, to the side of the inverter stand. AC disconnects mounted in this way should be supported well above the roof (600mm to bottom of enclosure), be fully accessible, and be heavy duty rated full load break models.

5.7.3 Inverter Topology

5.7.3.1 Micro-Inverter/Optimizer

Microinverters and optimizers which are equipped with quick connect style connections and do not have any field adjustable switches, terminals, fusing, or connections will be treated similar to modules as an infrequently serviced device. Provided a means to remotely query the inverters is provided as part of the design these will not be considered regularly serviced components, and permanent access and clearances will not be required. As noted previously, the Roof Access Plan shall include provisions for how these devices will be accessed if they need to be replaced.

5.7.3.2 String Inverter

String inverters shall be mounted wherever practicable to a wall (as opposed to roof mounted). Where inverters must be roof mounted, either anchored to standing seam (1/12 pitch or less), or ballasted, the design of the inverter stand shall be designed and sized to accommodate easy access, and a temporary location to stage/support sections of the inverter during maintenance (i.e. if a section of the inverter is removable) so that it does not get placed directly onto the roof surface during servicing.

> **Technical Rationale**
>
> UV can damage the inverters causing plastic components to prematurely age. If shade covers are not provided the inverters can overheat causing energy production issues through temperature derating or accelerate aging of internal components through thermal stresses.

Where roof mounted inverters are proposed, their location should be coordinated to take advantage of shelter/shading from rooftop obstructions (e.g. equipment) and shall be positioned such that outlets, vents, and stacks do not impact their operation. All wall or roof mounted inverters that could be exposed to directly sunlight shall have shade covers (either factory installed, or field installed) to prevent direct UV exposure to the device.

Racks supporting roof mounted inverters shall ensure the inverter (and associated AC disconnect, as required) is at least **600 mm (~ 2 ft)** above the roof surface to prevent snow from accumulating around the inverter fan inlet or outlets.

5.7.3.3 Central Inverter

Although not expected to be commonly deployed, if central inverters are considered for a project, they shall be located at grade, and in a serviceable location. They must be protected by a fenced enclosure, and ideally located on the east, or north side of the building to prevent overheating. Where water, snow, or ice may be shed into the enclosure it will be necessary to include a canopy or roof above the inverter enclosure.

Design teams proposing the use of a central inverter shall demonstrate to the City of Edmonton the value-added potential of permitting future DC coupled resources, and illustrate the incremental costs associated with additional wire (upsized to prevent losses) and capital cost associated with centralized inverter architecture vs. string inverter.

5.7.4 MPPT / Sub-Combiner Design

All strings connected to a common MPPT (either segregated within an inverter, or within an external sub-combiner) shall have the same length of strings. Modules shall be oriented similarly with as consistent as possible exposure. Where localized shading will exist, and effort shall be made to ensure that strings that will be impacted similarly are grouped to a common MPPT. Where larger variations are expected between strings, the design should consider using smaller inverters, optimizers, or an inverter with more MPPT's.

5.8 DC - Balance of System (BOS)

The DC balance of system components will vary from project-to-project based on the inverter topology selected and site-specific deployment considerations.

5.8.1 Rapid Shutdown

Where rapid shutdown hardware is mandated by CEC code, it is important to design the system so that all remote arrays are disconnected from either side of the exposed circuit (i.e. a circuit that travels > **2000 mm (6.6 ft)** between arrays). Where practicable the inverter shall be located within **1000 mm (3.3 ft)** of the array to minimize the need for additional rapid shutdown devices. Each device represents a potential point of failure, and design approaches should seek to minimize the total number of devices that require servicing.

The rapid shutdown initiator shall be located as specified by the CEC Section 64-218 and clarified in *Standata Electrical Safety Information Bulletin 18-CECI-64.* To remain consistent, the City of Edmonton would like the initiator to have standardized labeling and a site map located at DG Disconnect #1 indicating the location of the RSD Initiator.

5.8.2 Module Level Power Electronics (MLPE a.k.a. DC Optimizers)

As noted in *Table 1 – Energized Electrical Work Permit for Solar Arrays* in the *CoE Solar Photovoltaic Program Volume 4: Operations & Maintenance Guideline* live electrical work permits would be required for certain voltage classifications. Module level power electronics (MLPE) have the ability to limit the open-circuit and short circuit current of a given circuit.

In addition to the added safety benefit, where shading constraints exist that cannot be dealt with easily by string configuration, or site-specific conditions make implementing a string level rapid shutdown solution unviable then DC optimizers should be considered. Selected optimizers shall be compatible with the selected inverter for proper rapid shutdown functionality. Optimizers are well suited for residential and commercial projects and any projects with significant combustible construction.

It is critical that any projects designed with MLPE (e.g. DC optimizers) include a specific nomenclature for labeling optimizers, and specific guidelines in the construction drawings to ensure that optimizer serial numbers are tracked and located on the as-built roof plan.

5.8.3 Transition Box

Where it is necessary to transition from RPVU90 (DC string wiring) to a different conductor (e.g. TECK90) for remote arrays a NEMA 4 transition box shall be included within the design. All entries into the transition box shall be made with NEMX 4 rated grommets (Heyco or equivalent), and all connections shall be made with field terminated single contact (MC4 or equivalent) connectors. The use of DIN mounted transition strips or floating lug is not permitted as this creates a connection point that is difficult to service and will loosen due to the temperature cycling during operation.

5.9 AC Wiring

5.9.1 Conductor Material

All AC circuits are to be Copper (Cu).

5.9.2 Conductor Jacket

All jackets shall be selected based on exposure class and rating. Any conductors exposed to outdoor temperatures run within conduit shall be RW90, RWU90, TECK90, or ACWU90 or equivalent. All cables shall be protected where they enter and exit an enclosure, conduit, or connector.

5.9.3 Cable Entries

All cable entries shall be installed in the bottom, or, if insufficient room for entry or routing of cables, in the side of the enclosure. When side entry is used, a continuous circular gasket should be used to ensure a complete and continuous seal around the penetration. Where a gasket cannot be accommodated, the addition of a UV rated silicone sealant may be used. Under no circumstance shall top entry be permitted unless it is through a manufacturer specific hub designed for that purpose and no other entry option exists.

All threaded cable entries (e.g. conduit, TECK connections etc.) regardless of size shall have grommets installed on exposed threads, and inner jacket (where applicable) shall extend at least **25 mm (1”)** past the conduit/connector.

5.9.4 AC Bonding Methods (e.g. dissimilar metals etc.)

Where AC bonding systems are being used as ground reference for the solar photovoltaic modules and/or inverters (as may be required by the equipment) grounding methods according to CEC shall apply. Where this approach is being taken in all copper systems irreversible crimp C-taps shall be used to connect bond wires.

5.10 AC Balance of System

5.10.1 Coordination Study

A coordination study shall be required where the interconnection point is downstream (on the load side) of the primary switchgear or where there are two (2) or more breakers in series including the main breaker and any associated DG system breakers. In this case, the coordination study shall be used to ensure that all existing and new devices are properly coordinated to control faults and minimize service interruptions.

5.10.2 Arc Flash Study

All serviceable equipment within the solar photovoltaic system (e.g. inverters, combiners, disconnects, transformers etc.) shall be included within a solar photovoltaic system arc flash study. Where possible, this study should be completed using upstream conditions associated with existing building infrastructure and detailed utility provided fault current levels. This Arc Flash study shall be done in accordance with IEEE-1584 and also include any DC equipment where routine servicing may be required (e.g. combiner or rapid shutdown boxes).

5.10.3 Equipment at Grade

All equipment at grade, where not protected by concrete barriers or curbs, shall have bollards installed to protect the equipment. These bollards are to be made from **100 mm (4")** galvanized steel piles that are filled with concrete (or grout). Bollards are to be positioned no less than **1800 mm (6 ft)** apart. All bollards are to have plastic (yellow coloured) plastic sleeves installed overtop of them. Where space is constrained, it is acceptable to address the bollard requirements by using oversized 100 mm (4") fence posts and filling them with concrete (or grout).

Where practicable, if equipment can be configured with tamper proof fasteners and enclosures equipped with tamperproof fasteners (e.g. transformers, AC combiner panels) or locks (for disconnects), providing fencing may not be required.

Otherwise, all equipment located at grade shall be protected from unauthorized access through the use of chain link fencing and gates. Equipment clearances shall be measured (minimum required 1m clearance in front of all accessible equipment) when gates are OPEN and posts shall be positioned so that they do not block serviceable sides of the equipment mounted at grade. Adequate spacing around all equipment is to be provided in order to safely operate equipment and any integral bypass switches.

Where direct sunlight can heat up equipment, awnings or plastic shrouds should be installed in the chain link fencing to reduce the amount of solar incident directly on the equipment.

5.10.4 AC Disconnects

All disconnects used within the system shall be heavy duty rated, and are to be specified with the appropriate rating, protection, and mounting for the application.

5.10.4.1 Type / Style

All switches are to comply with CSA C22.2 No 4. and fuse holder assembly shall comply with CSA C22.2 No 39. All switches shall be heavy duty rated for the duty cycle of solar photovoltaic systems (standard Air Conditioning disconnects are not acceptable). All disconnects shall be mounted vertically unless specifically noted as NEMA 4X.

> **Technical Rationale**
>
> Standard rated disconnects (like those used for HVAC equipment) when exposed to sustained operation of a solar photovoltaic system during its peak generating hours can fail due to overheating.

5.10.4.2 LOTO considerations

Disconnects used for key isolation points (such as DG Disconnect #1 and those required by the Wires Owner) shall include a visible break. Breakers (without visible break) are acceptable for inverter isolation disconnects.

All switches shall be lockable in the ‘open’ position and visually identifiable as disconnected. Where the switch is accessible to the general public a means of securing the disconnect shall be included. For larger switches this could mean a U-bolt (permits dual access) with locks on either end for the Owner and Wires Owner, or for smaller switches a fenced or mesh enclosure that is lockable with a U-bolt would be acceptable.

5.10.4.3 Servicing Considerations

Electrical equipment enclosures shall be equipped with a mechanically interlocked door to prevent opening when handle is in the ON position. This shall include ON-OFF switch position indication on switch enclosure cover. A bypass shall be included for in the switch, and the equipment layout shall permit access to the bypass for IR imaging purposes.

5.10.5 Intermediate Transformer

It is common for solar photovoltaic systems comprised of string inverters to require a transformer to step up (or in some cases step down) system voltages from the inverter output voltage to the area electrical power system (EPS) voltage. Where large distribution infrastructure exists the transformer also provides a means of limiting fault current to downstream devices (e.g. inverters). Where possible avoid the use of additional transformers to maximize the efficiency of the system. With higher DC input voltage inverters (e.g. 1500 VDC) there are more options for direct 600VAC output which can correlate well to existing service voltages on commercial projects.

5.10.5.1 Sizing

The transformer and associated disconnects shall be sized in accordance with the max continuous loading or ‘fit for purpose’ requirement, isolation/protection requirements, etc. Solar PV systems operate at continuous output for many hours in a day, and those corresponding to maximum thermal conditions.

Ensure compliance with CEC Sections 84-012, 64-058, and 26-250. In no case shall transformer sizing (kVA) be less than combined inverter sizing (kWac). Where concern exists regarding ability for the transformer to maintain peak output conditions, considerations should be made to include a 125% sizing factor into the calculations.

From an efficiency and performance perspective it is best to have a correctly sized transformer that has the capacity to withstand the conditions it will confront when integrated into a solar photovoltaic system. Effort should be made to consider placing the transformer in a shaded, or partially shaded location as opposed to exposing it to full sunlight during the generating peak hours (e.g., 2 hours on either side of solar noon) to reduce the effects of temperature derating.

Conventional distribution transformers may not be suitably rated for the duty cycle and loading of a solar photovoltaic system. Consider the impact of generation on upstream equipment.

5.10.5.2 Type

Where a transformer is required it shall be an isolation transformer. Unless otherwise specified by the inverter manufacturer connection configurations that are acceptable shall be:

Table 11 - Transformer Windings

Area EPS Winding	Primary Winding (Grid)	Secondary Winding (PV System)	Application Note
4-Wire WYE	3W – DELTA	4W – WYE	*A WYE-WYE transformer topology should be **avoided.***
3-Wire Delta	3W – DELTA	4W – WYE	*DELTA:DELTA transformer topology should be **avoided***

If the inverter manufacture requires a WYE:WYE transformer, it shall not be an autotransformer, and it may not be possible to rely on inverter based passive anti-islanding alone. It may be necessary for a secondary means of ensuring the correct anti-islanding response is achieved (e.g. a protection relay). Unless specifically required by the application or manufacturer, a 3W DELTA on the secondary or PV System side of the transformer shall not be permitted unless specifically required by the inverter manufacturer.

5.10.5.3 Location

The transformer shall be placed in a location approved by the City of Edmonton. There shall be adequate clearance around the transformer to permit servicing and proper ventilation. Access in and around the transformer shall be controllable to permit safe servicing of the equipment without risk to building occupants or staff. In all cases, structural and mechanical loading shall be confirmed by the EoR in accordance with good engineering practice.

Considerations regarding location and application:

Table 12 - Transformer Location Considerations

Transformer Location	Application Considerations
Indoor	Any transformers located indoors shall consider the impact of heat losses on the building HVAC equipment. Transformer connections shall be reachable with minimum **1000 mm** clearance in front of all outer guards that cover connections.
Outdoor – At Grade	Transformer shall be located away from regular pedestrian and vehicular travel areas. Where the transformer is in close proximity to travel lanes (i.e. within 5000 mm) and there are no concrete barriers or curbs, appropriate bollards and fencing are required.
Outdoor – Rooftop	Although less common, in some cases it may be appropriate to install transformers at the roof level. The specific connection details shall be reviewed with a structural engineer. It is typically to see additional dunnage/supports being provided to distribute the transformer loading across multiple roofing members. For rooftop installations it is still recommended that vandal resistant fasteners be used to avoid confusion with standard distribution transformers at the facility.

5.10.5.4 Efficiency

All transformers are to be selected to comply with % NRCAN2019 dry-type transformer efficiency (e.g. input energy vs. output energy) at all of its operating conditions. Designers shall request performance curves from prospective equipment manufacturers to confirm efficiency through all the standard operating conditions and submit these as part of the Detailed Engineering Package.

5.10.5.5 K-Factor

The harmonic distortion of the non-linear inverters shall be calculated to determine the appropriate K-rating for the transformer. Where manufacturers are unable to provide specific harmonics data for their device, the electrical Engineer-of-Record shall determine an appropriate transformer in accordance with good engineering practice. In existing facilities, it may be necessary to measure existing harmonics to determine if a harmonic mitigation transformer is required.

5.10.5.6 Isolation / Anchoring

All transformers mounted within and on top of buildings shall include mechanical isolation and shall be anchored to prevent shifting or movement caused by any seismic activity.

5.10.5.7 Enclosure (e.g. tamper proof)

The enclosure shall be rated for the application, exposure, ventilation and location. If a project is likely to be sprinklered in the future, hoods necessary to achieve a NEMA 3R shall be specified.

5.10.6 AC Transient Voltage Surge Suppressors (TVSS)

Where long cable runs exist or where there is proven issues with transients and surges, a TVSS should be considered in close proximity to, or ideally within, the AC Combiner panel. In all cases the TVSS shall be connected to an over current protection device (e.g. fusing, or breaker) directly connected to the piece of equipment it is protecting.

> **Technical Rationale**
>
> When TVSS fail, they commonly fail to a short. When connected directly to a bus (either AC or DC) that can result in an uncontrolled short which can lead to a secondary thermal event and damage to the equipment it was installed to protect.

5.11 Monitoring

5.11.1 Customer Metering Equipment

The City of Edmonton requires an energy meter for the Host Facility, and the Solar Photovoltaic Project. Where an existing customer meter is not installed at the facility, the solar Project shall provide for one within its design. All metering equipment shall comply with the City of Edmonton requirements as stipulated in *Metering & Power Monitoring* section of the *Consultant Manual (Vol2 – Technical Guidelines v4.0 – Section: 4.12.7.3).*

All meters shall interface with the City of Edmonton facility metering system to monitor electricity consumed/generated in terms of kW and kWh for GHG accounting purposes. Additional individual meters may be required to monitor any other onsite generation sources. Meters specified for customer metering shall be native BACnet compatible, with Multiple Spanning Tree Protocol (MSTP) where required in order to integrate seamlessly into the City of Edmonton existing Building Automation System (BAS) and metering platform.

Design drawings shall specify the necessary current transformers or transducers (CTs) and potential transformers (PTs) sized to the load, with directions on where to be installed within electrical distribution equipment. All CTs shall be of the solid-core revenue grade donut type. Voltage taps (or PTs) shall be factory assembled and come complete with electrical disconnects and fuses mounted in a separate enclosure.

5.11.2 Solar Monitoring System Criteria

All projects shall be equipped with a monitoring system that can track production, evaluate performance and identify through fault alerts, if there are issues with the system. The specific system can be either an inverter manufacturer specific product, or a third-party monitoring package provided it includes the following capabilities.

5.11.2.1 Data Acquisition System (DAS)

Designs shall provide for a fully functioning monitoring system capable of sensing, collecting, transferring, storing, and publishing the data as specified herein, that has been setup, commissioned, and is connected to the network available onsite (using DHCP).

The system shall offer a web-based application programming interface (API) that allows the following access, after entering the required security credentials (i.e. username and password). The owner shall be granted full administrative access to enable:

- 24-hour, 7 days per week year-round access
- Data to be downloaded remotely using any computer with internet connectivity,
- The Owner (or Operator) to make administrative changes including setting-up alarms and outbound email alerts, adding new users, accessing and downloading data and project documentation,

Data measured by the sensors listed below must be collected and stored onsite with at least 15-minute intervals for 60 months (or smaller intervals of time, for longer duration storage). The data logger provided as part of the system must be equipped with an internal SD slot for additional storage and transfer of data. Data shall be accessible using the web-based API. Data must be able to be downloaded in *.csv (or equivalent) format. The City of Edmonton shall be able to download data collected by the monitoring system remotely and manually (onsite), free-of-charge, in perpetuity.

5.11.2.2 Monitoring Points (e.g. Irradiance, Temperature etc.)

A reference cell and temperature sensor shall be provided for each project to provide onsite data pertaining to amount of irradiance available and ambient temperature onsite. All equipment shall be rated for exposure to temperatures between -40° to 65° C.

5.11.2.3 Inverter OEM Monitoring

All inverters shall be hard wired together using RS485/Modbus compatible wiring. This shall be connected to the inverter gateway necessary to remotely access inverter output, upgrade firmware, or verify system performance. All projects shall provide a login and administrative access to the inverter equipment monitoring platform.

The system shall offer a web-based portal that can be customized with the Owner's corporate logo and colours to support diagnostic review of the equipment:

- Real-time system data depicted graphically in gauges or charts including electrical energy generated (kWh) by the entire solar PV system
- Daily, weekly, monthly, and yearly historical consumption and generation data
- Live weather data from temperature and irradiance reference cell.
- Equivalences showing generated power as gas saved, carbon offset, trees planted, etc. (if available) and other desired educational content about solar power.
- Status of the system, overall indication if running normally, as expected, or in a state of fault or error (communications or similar)

Where the City of Edmonton has an existing dashboard for that inverter make, the project shall be paired with that login to ensure it is integrated into a consistent monitoring platform. Full administrative privileges for the project, parameters, and access shall be granted to the City as the site owner.

5.11.3 IT Infrastructure

Where possible the monitoring system should be coordinated with the City of Edmonton IT equipment and a hard-wired Local Area Network (LAN) connection should be provided. In some cases, subject to approval by City of Edmonton approval, a wireless modem may be acceptable if it is technically challenging or cost prohibitive to provide a LAN connection.

5.12 Labeling & Identification

5.12.1 Nomenclature

All standalone AC Disconnects shall be labeled as **DG System Disconnect #** - with the count starting from **DG#1** the fused disconnect closest to the switchgear and incrementing as the project moves through the system towards the inverters. Inverter isolation means shall be numbered based on the inverter that it serves.

Table 13 - Naming Conventions

Device	Label	Application
AC Disconnects	DG Disconnect #	With the # count starting from DG#1 the fused disconnect closest to the switchgear and incrementing as the project moves through the system.
Inverter AC Isolation (Breaker or Disconnect)	Inverter #	With the inverter numbering starting from the inverter in the north-west (top left) corner of the site and incrementing moving east, and south.
String Wiring	INV## - MPPT# - STR##	String Wiring must also include the Inverter Number and String Number and nomenclature shall match the Issued for Construction drawings. String numbering shall be per inverter and not cumulative across the site.

5.12.2 String Labeling

All source string circuits shall be clearly identified and labeled (within enclosures) for polarity and string by String Number and Inverter Number (INV# - MPPT# S#-##). BLACK is the accepted color-coding for negative conductors and RED is the accepted color-coding for positive (ungrounded) conductors. DC conductors shall be sourced with a coloured jacket or labeled with heat shrink for the length of the exposed jacket.

Figure 17 – String Labeling (Sample)

5.12.3 Equipment Identification

Each major PV system component (including inverters, disconnects, transformers, meters, and overcurrent devices) shall be clearly identified and labeled consistently within the drawings. Names for equipment shall be consistently used in accordance with the nomenclature (section 5.12.1). All major equipment shall be labeled using permanent, self-adhesive and shall be black with white letters, where all danger or warning labels are to be red with white letters. As per CEC, letters for main DG warnings should be minimum 9.5mm in height ,

Figure 18 - Equipment Labeling (Sample)

5.12.1 Site Map

A high-level overview of the site, location of key equipment (e.g. Main Switchgear, DG Disconnect #1, the Rapid Shutdown Initiator, and Rooftop Access) shall be included. This site map shall be posted at DG Disconnect #1, and at the Rapid Shutdown Initiator Device / Utility Isolation Disconnect. This site map shall also be included within the site access package so that all staff needing to access the site have an overview of the system and equipment locations.

5.12.2 Single Line Diagram

A simplified single-line diagram of the as-built system shall be provided on 11” x 17” permanent, self-adhesive, engraved black stock with white core plastic with a minimum thickness 1/16” or an approved equal. A copy of this diagram shall be mounted on the switchgear or adjacent to DG Disconnect #1, any Utility Isolation disconnects, and the Rapid Shutdown Initiation Disconnect. A laminated as-built single line drawing may be substituted for indoor mounted equipment only, provided it is permanently affixed behind plexiglass.

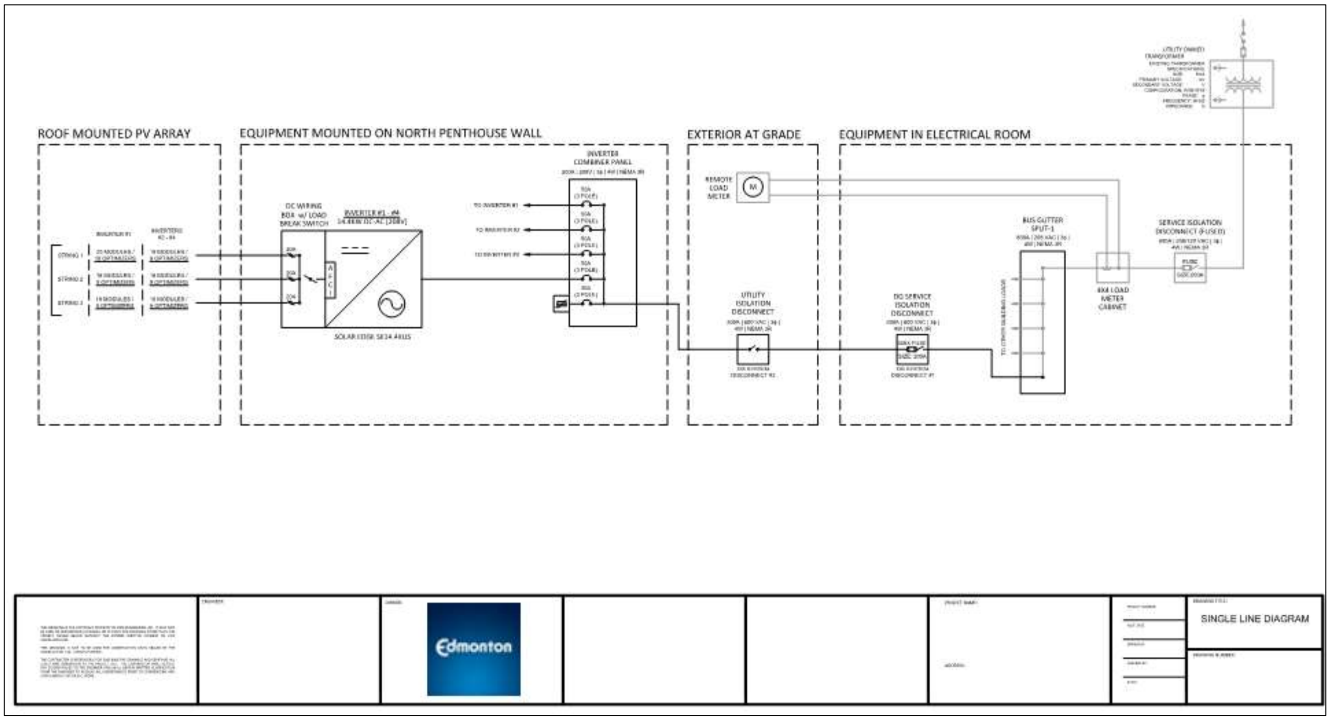


Figure 19 – Lamacoid SLD (Sample)

6 PV System Generation Expectations

6.1 Generation Basis of Modeling

Annual energy estimates have a projected uncertainty of +/- 10% based on nominal seasonal variations and unforeseen conditions that may occur. The expected performance of a PV system can be significantly impacted by the design parameters and assumptions included in the generation model. As such we believe it is critical to define the base parameters, along with detailed design variables, that should be included in any generation estimate.

Table 14 - Modeling Parameters

Basis of Simulation Assumptions	Parameter	Site Specific Notes
Detailed 3-D Near Shading Model	Site specific	Simulations should include a detailed shading/3D geometry for rooftop equipment and differing roof elevations. Obstruction heights (e.g. RTUs, Trees etc.) should be field verified
Site Details (Orientation)	Azimuth: -° Module Tilt: -°	To be based on site observations, defined racking/module layout and Satellite images of site.
Annual Soiling	-1.0%	Base assumption of 1%, if it is a site near dust emitters (e.g. landfill, field, etc.) then a higher value would be appropriate (e.g. 2%)
Snow Soiling	Monthly adjustments made to October through April soiling factor	Source for each site, nearest source for historical data) snow days data: NRCan Average days lost was calculated as follows: a) Snow days in excess of 5 cm snowfall [X] b) Snow days in excess of 10 cm snowfall [Y] c) Weighted average: 75%*X + 25%*Y

<table>
<tr><td></td><td></td><td>d) Days of lost output is based on tilt:
<table><tr><th colspan="4">Days Lost per Heavy Snow Day</th></tr><tr><th></th><th>10°</th><th>20°</th><th>30°</th></tr><tr><td>Oct</td><td>1</td><td>1</td><td>1</td></tr><tr><td>Nov</td><td>1.5</td><td>1</td><td>1</td></tr><tr><td>Dec</td><td>5</td><td>3</td><td>2</td></tr><tr><td>Jan</td><td>7</td><td>4</td><td>3</td></tr><tr><td>Feb</td><td>7</td><td>4</td><td>3</td></tr><tr><td>Mar</td><td>4</td><td>3</td><td>2</td></tr><tr><td>Apr</td><td>1.5</td><td>1</td><td>1</td></tr></table>Some pre-processing of the information is necessary in order to approximate snow coverage and soiling. As a result, we draw from Environment Canada historical snowfall/precipitation models to complete that stage of the analysis.</td></tr>
<tr><td>Field Thermal Loss Factor</td><td>15 - 29.0W/m²k</td><td>Value is based on the nature of the racking system, how much excess heat can escape, with wind loss factor built into the overall thermal parameter.
1. Ground mount: 29 W/m² K
2. Standard flat rooftop: 20 W/m² K
3. Flush mount: 15 W/m² K</td></tr>
<tr><td>Module Quality Loss</td><td>Module Datasheet / Database</td><td>This is to be selected based on the PV Module Manufacturer STC datasheet value and/or dataset included in the simulation software. The available tolerance for PV models range from 0~+5W.</td></tr>
<tr><td>Module Mismatch Losses</td><td>-1.0%</td><td>Without detailed manufacturer information concerning Module flash test data and common Isc module sorting, the industry standard loss should be used. In parametric runs where DC-DC optimizers are considered, this value is set to 0% for optimized sections of the system.</td></tr>
<tr><td>String Mismatch Losses</td><td>-1.0%</td><td>Due to strings being run between sections of array (N/S inter-row) with differing vegetation/terrain setups, there is a resulting negative, where not all modules in a string are exposed to the same levels of irradiance. In parametric runs where DC-DC optimizers are considered, this value is set to 0% for optimized sections of the system.</td></tr>
<tr><td>Light Induced Degradation</td><td>-1.5%</td><td>Without detailed information from the manufacturer on an expected amount, this standard value is a reasonable placeholder for Tier 1 module suppliers.</td></tr>
<tr><td>Ohmic Wire Losses (DC)</td><td>-1.0%</td><td rowspan="2">These values are used as placeholder values for worse case loss profile (Refer to section 4.1.3 for maximum upset limits).</td></tr>
<tr><td>AC Ohmic Loss</td><td>-1.5%</td></tr>
<tr><td>Inverter (CEC) Efficiency</td><td>Manufacturer Specific Curves</td><td>Inverter Efficiency curves included in the software modeling should be included.</td></tr>
<tr><td>Transformer</td><td>0.5% (no load)
2.0% (resistive)</td><td>Values shown are placeholders. Shop drawings indicating efficiency curves and no load losses should be used.</td></tr>
<tr><td>System Downtime / Availability</td><td>0.5%</td><td>Downtime for initial system commissioning and future O&M maintenance to be estimated to be 2.0 days per year.</td></tr>
</table>

SCHEDULE 1 –Concept Design Package - Submission Checklist

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

☐ **Structural Report**

- Investigation:
- Structural assessment:
- Design of reinforcing:
- Reinforcement Strategy (if required):

☐ **Site Plan / Context Plan**

- Indicating primary streets and access,
- Illustrating location of solar PV equipment.

☐ **Roof Plan Drawing**

- showing proposed array configuration and associated setbacks,
- Identifying rooftop mounted equipment (e.g. inverters, panel boards etc.),
- Identifying maintenance pathways for rooftop equipment (existing and new).
- Access considerations (e.g. for servicing, maintenance etc.)

☐ **Single Line Drawing**

- Indicating major equipment (inverters, panel boards, transformer disconnects),
- Interconnection location and method,
- DC array configuration.

☐ **Equipment Layout** – a high level overview of major equipment locations

- At-Grade Equipment (e.g. Disconnects, and Transformer if applicable),
- Interior Equipment (e.g. electrical room, or ancillary spaces).

☐ **Datasheets (major equipment)**

- Modules,
- Racking,
- Inverter.

SCHEDULE 2 –Detailed Engineering Package - Submission Checklist

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

☐ **Structural Design**

- Design of reinforcing (if required),
- Racking shop drawing package.

☐ **Site Plan / Context Plan** (updated as required)

☐ **Roof Plan Drawing**

- Revised module configuration/layout – based on racking engineering,
- Update setbacks for mechanical equipment servicing based on CD review,
- Details showing module stringing and inverter allocation (string numbering).

☐ **Single Line Drawing**

- Detailed Sizing and Rating for Equipment / equipment schedules,
- Wire / Conduit Sizing,
- Over Current Protection (indicating available fault current/rating),
- DC string/inverter configuration.

☐ **Equipment Layout** – dimensioned drawings showing existing and new equipment

- Plan View / Elevation of all new equipment (existing to be shown in grey).

☐ **Electrical / Mechanical Details**

- Bonding / grounding details,
- Transition boxes (if applicable),
- Wire management (support and protection),
- Wiring details and cable support,
- Inverter/combiner mounting,
- Roof/wall penetration details.

☐ **Detailed Wire Sizing & Losses**

- Wire length / type / size,
- Wire loss calculations (DC/AC).

☐ **Monitoring System**

☐ **Labeling Diagrams**

☐ **PV System Generation Results**

SCHEDULE 3 –Site Safety Data Sheet (SSDS)

SECTION 1 – EMERGENCY RESPONSE CONTACT INFORMATION			
Site Address:			
Site Owner:			
Nearest Hospital			
Site Status:	IN CONSTRUCTION	IN OPERATION	OFFLINE

SECTION 2 - HAZARDS IDENTIFICATION SUMMARY	
Physical	
Working Areas	Personal Protective Equipment (PPE)
Roof Top Array (DC Combiners / Junction Boxes)	Hardhat, Boots, Limited distance 6 ft from edge of roof at all times, Flash Vest, Safety glasses or safety goggles, Hearing
At Grade Equipment - electrical enclosure	Hardhat, Boots, Flash Vest, Safety glasses or safety goggles, Hearing protection,
Access Control (for servicing / imaging)	Flash Vest, Secondary person stationed outside of electrical enclosure, Safety glasses or safety goggles, Hearing protection,

Shock		
	Personal Protective Equipment	
AC	Maximum Voltage: _______ VAC	Class ___ Gloves
DC	Maximum Voltage: _______ VDC	Class ___ Gloves

Maximum Exposure (by Location)		
	Personal Protective Equipment	
AT-GRADE	*Serviced Equipment: DG1, DG2* Maximum Voltage: ### VAC Max AIB Incident Energy: ## cal/cm^2 Max Arc Flash Boundary: ## in (~# ft)	Category # (## cal/cm^2 max)
AT-GRADE	*Serviced Equipment: AC Combiner / Txr* Maximum Voltage: ### VDC Max AIB Incident Energy: #.# cal/cm^2 Max Arc Flash Boundary:	Category # (## cal/cm^2 max)
ROOFTOP	*Serviced Equipment: Inverters* Maximum Voltage: ### VDC Max AIB Incident Energy: ## cal/cm^2 Max Arc Flash Boundary:	Category # (# cal/cm^2 max)