City of Edmonton

Solar Photovoltaic Program

Operations & Maintenance Guideline

Volume 4

Edmonton Tower
10111 – 104 Avenue
Edmonton, Alberta
T5J 0J4

COE-IM-GUIDE-0006
Version: 02
Issued: 2020-11-12

Prepared for

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

Prepared by

Zon Engineering Inc.
SkyFire Energy Inc.

Authorized By

Jordan Hoogendam	
Name	Signature
Senior Engineer, Zon Engineering Inc.	2020-11-12
Title	Date

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.

Report Version History

- REV01 – September 25, 2020 – Released
- REV02 – November 13, 2020 – Authorized Final

Printed or downloaded copies of this document are not controlled and may not be the current version.

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

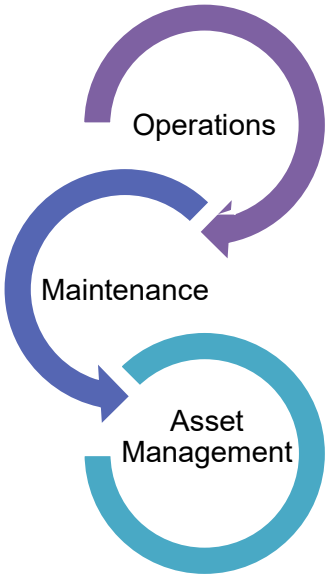
Table of Contents

List of Figures

List of Tables

1 Overview

The objective of this Operations & Maintenance guideline is to define recommended operational and safety practice for solar photovoltaic projects installed on City of Edmonton facilities. This guideline is to be read in conjunction with all of the relevant codes and standards (per Section 2.0) and has been developed to consider the safety, durability and performance of solar photovoltaic systems installed on City of Edmonton Facilities.



1.1 Purpose & Scope

This document is intended to provide a guideline for use by City of Edmonton staff and sub-contractors (as may be required) to provide operations & maintenance services for City owned solar photovoltaic assets. The contents of this guideline do not supersede any requirements of Authorities Having Jurisdiction (AHJ) but seek to establish the best practice expectations the City of Edmonton has for its projects. It is to be read in conjunction with *Volume 3 – Construction Guideline* for specifics on reporting and benchmarking the solar photovoltaic systems.

1.2 Definitions

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

- Regularly Serviced Equipment – is equipment that will require at a minimum annual access to tighten connections, replace filters, or recalibrate. Examples include: Combiner Boxes, Inverters, switches and breakers etc.
- Infrequently Serviced Equipment – is equipment that requires access only if it is damaged, or non-functional. Examples include: Solar PV modules, Optimizers, microinverters etc.
- Exposed (based on CSA Z462 as applied to energized bare electrical conductors or circuit parts) – capable of being inadvertently touched or approached nearer than a safe distance by a person. This term is applied to electrical conductors or circuit parts that are not suitably guarded or insulated. E.g. bare terminals within equipment, unconnected PV module whips etc.

2 Referenced Standards

2.1 Construction Standards

2.1.1 Authorities Having Jurisdiction

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

2.1.2 Safety Standards

- *Alberta Occupational Health and Safety Act*
- *Alberta Occupational Health and Safety Code*
- *CSZ Z460-2020 - Control of Hazardous Energy ‑ Lockout and Other Methods*
- *CSA Z462-2020 - Workplace Electrical Safety*

2.1.3 Technical Standards

Canadian Standards Association (CSA)

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

Institute of Electrical and Electronics Engineers (IEEE)

- *1547-2018 - IEEE Standard for Interconnecting Distributed Resources with EPS*
- *1584-2018 - IEEE Guide for Performing Arc-Flash Hazard Calculations*

Underwriters Laboratory (UL)

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

International Electrotechnical Commission (IEC)

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

National Renewable Energy Laboratory (NREL)

- *Best Practices for Operation and Maintenance 2nd Edition*
- *Best Practices for Operation and Maintenance of PV and Energy Storage Systems; 3rd Edition*

2.1.4 Solar Program Document Standards

- *City of Edmonton Solar Photovoltaic Program – Volume 1: Site Selection Guideline*
- *City of Edmonton Solar Photovoltaic Program – Volume 2: Design Guideline*
- *City of Edmonton Solar Photovoltaic Program – Volume 3: Construction Guideline*
- *City of Edmonton Solar Photovoltaic Program – Volume 5: Asset Management Guideline*

3 Environment, Health & Safety

The City Manager acknowledges as part of the Occupational Health & Safety program that all occupational injuries and illnesses can be prevented through an effective safety management system. The intent of this guideline is to develop an operations and maintenance program that has safety as its central focus. This includes safety to the facilities, staff, and operators involved with maintaining the project. Staff shall consider the following aspects as it relates to their activities during preventative and corrective maintenance activities:

3.1 Site Orientation

Solar PV field maintenance staff are expected to have obtained all site access information as noted in SCHEDULE 1 and identified all key areas of access and egress on a site. This site orientation should include appropriate locations for service technicians to locate vehicles (for parking, and equipment delivery) and facilitate material handling).

3.1.1 Roof Access/WAH Awareness

As noted within the site specific Roof Access Plan, staff are expected to field verify the roof access requirements and follow all guidelines noted in "Part 9: Fall Protection" of the occupational Health and Safety Code. Specific attention should be given to working at heights considerations when troubleshooting or testing solar photovoltaic systems as most of the system is typically located in elevated areas (e.g. for rooftop mounted equipment) where bump lines or guard rails may not be present.

3.1.2 Electrical Safety Awareness

Ensure a Site Safety Data Sheet (SSDS) has been prepared by the Engineer-of-Record (EOR) responsible for the design of the site (as stipulated within *Volume 2 – Design Guideline*). All field staff shall review the datasheet and ensure that shock and arc flash personal protective equipment (PPE) appropriate for the site is within the field staffs gear, and in good condition. Contractors shall be made aware that solar photovoltaic modules are always energized and live, and as such all service staff shall ensure they have appropriately rated electrical safety voltage rated gloves with properly sized leather protectors (refer to Section 3.3.1 below).

The City of Edmonton has developed a set of specific safety practices relating to working in and around Solar arrays. The permits required are defined based on the operating voltage of the component or circuit that is being serviced:

Table 1 – Energized Electrical Work Permit for Solar Arrays

Voltage Classification	Required Work Permits
<30VDC	Work Permit Not Required as per CSA Z462.
30VDC < 96VDC*	Energized Electrical Work Permit Not Required if following CoE FMS Electrical Safe Job Procedures
>96VDC*	Energized Electrical Work Permit Required for all work other than testing and troubleshooting as per Z462

All service technicians shall be fully briefed on the most recent City of Edmonton electrical safety requirements, and all work on equipment within the City of Edmonton control shall be undertaken in accordance with these requirements.

3.1.3 Hazardous Area Awareness

Signage shall be installed onsite at all points of access to the rooftop, or other areas with high voltage (e.g. DC equipment operating at or above 1000 VDC). The signage shall be in place indicating the operating voltages, orientation required and indicating restriction of unsupervised access to qualified service personnel only.

All equipment shall be labeled with shock and arc flash warning labels generated in accordance with IEEE 1584.

Figure 1 – Examples of Arc Flash & Shock Hazard Labels

Only qualified personnel with the appropriate PPE shall be accessing or be present within the limited approach distance of this equipment during any servicing.

3.2 Physical Safety

All service personnel whether employed directly by the City of Edmonton or a sub-contractor shall be responsible to ensure they are fully equipped with the necessary PPE to complete the job. The PPE must be rated for the application and current in terms of relevant test standards.

3.2.1 General Personal Protective Equipment (PPE)

Staff onsite shall be wearing the following PPE to protect themselves:

- Hard Hat
- Safety Vest
- Safety Glasses

- Ear Plugs
- Safety Gloves (refer to Section 3.3.1 below)
- Steel or Composite toed Work boots
- Pants that cover the ankle (shorts are not to be worn)

3.2.2 Working at Heights (WAH) Equipment

Fall arrest system must be employed on all pitched roofs, regardless of slope and material construction. This system must be reviewed/approved by an authorized individual on the contractor's staff. For flat roofs, all employees must stay back behind existing bump lines or **4.0 m** (~13 ft) from the roof edge or utilize an approved fall protection or travel restraint system.

For elevated work where the limits of approach to roof edges, skylights, or other features mandates it; staff shall use appropriately fitting body harnesses, lanyards, and associated safety lines secured to the designated points to safely access the array. Where practicable staff can make use of travel restraint systems which prevent access to roof edges. All fall arrest systems shall be as indicated in the Roof Access Plan and have been approved for use by the City of Edmonton. Variation from these plans is only permitted with written approval from the appropriate City of Edmonton safety manager.

3.3 Electrical Safety

Solar PV systems warrant special consideration and care with respect to electrical safety. O&M technicians and electricians require specialized training and experience working with solar PV systems to ensure a full understanding of the potential electrical hazards that can exist.

Figure 2 – Examples of Rubber Insulating Safety Gloves

3.3.1 Electrical Protective Equipment

For work where City of Edmonton staff, or associated contractors, are involved, the expectation is that all staff attending the site shall ensure they have the following Personal Protective Equipment (PPE)

- **Electrical - Standard:** Electrical Safety voltage rated gloves Class Designation of 0 (or higher – and subject to semi-annual testing/recertification) with leather protective gloves are to be used, and documentation provided as to recent recertification (within 6 months). These gloves are to be worn at all times when opening/closing or entering enclosures, making contact with the modules or racking, and when investigating a fault.

Safety Comment

Black coloured gloves have the highest arc blast resistance rating when paired with appropriate leather covers.

- **Electrical – Medium Risk PPE Category 2** (*as defined by CSA Z462):* in addition to the aforementioned PPE, face shields with balaclavas for medium risk activities (i.e. IV Curve tracing, insulation resistance testing etc.) shall be worn in accordance with the SSDS and Arc Flash & Shock Hazard Warning Labels. .
- **Electrical – High Risk PPE Category 4** (*as defined by CSA Z462):* in addition to the aforementioned PPE, use of a 40 cal arc flash suit including coveralls, full face mask/shield (and if needed a respirator) shall be worn in accordance with the SSDS and Arc Flash & Shock Hazard Warning Labels.

Staff shall be trained in the appropriate care, and cleaning of protective clothing and components. Daily visual inspections prior to and following use of the equipment shall be completed noting any issues of concern.

3.3.2 Lock-Out / Tag-Out (LOTO)

All activities being performed by maintenance staff are to comply with the "Hazardous Energy Isolation Program – 2020". This program and subsequent checklist are to ensure the proper procedures and equipment are used while performing the appropriate maintenance activities. This program has been developed based on the CSA Z460 Standard for Lock-out / Tag-Out (LOTO) procedures.

Further to this program there are specific aspects about solar photovoltaic systems which make it difficult, or in some cases impossible to fully control the hazardous energy. This is due to the inherent nature of solar photovoltaic modules which are always "ON" or energized. Although it is anticipated that future development of module level electronics will mitigate this to some extent - it is important to treat solar photovoltaic modules as containing a specific shock potential.

The procedures and equipment include, but are not limited to:

- Responsibilities for the Director, Managers, Foreman & Workers
- Lockout & Tag-Out methods
- Procedure for lock and/or tag removal

Safety Comment

Field technicians should be provided multiple locks and tags, as issues on solar PV systems typically require both AC and DC related equipment lock-out.

Attention should be paid for a Solar PV system where there are parallel power sources (e.g. grid and inverters) to ensure that switches and disconnects which may be energized on both sides (e.g. in standard, or fault condition) depending on the system configuration requires safety checks to be completed on all line voltage connection points within an enclosure to confirm it is fully de-energized.

3.3.3 Ground Fault Investigation

Field technicians must be trained to always check for ground faults. If there is a ground fault, there may be a voltage potential between any of the photovoltaic equipment and ground (or a ground reference). Always assume until confirmed via onsite testing that a bonding system may be compromised. For grounded conductors check that the normally grounded pole is properly grounded and has not been energized by a fault. Specific attention should be paid if it is a grounded DC system (e.g. transformer based inverters) to ensure that multiple faults, or non-functional Ground Fault Interrupt (GFI) circuits are not creating a "blind spot" which bypasses conventional GFI protection.

3.4 Environmental (e.g. spill management)

Although this does not represent a major concern on solar photovoltaic projects, it is important to refer to the City of Edmonton's Enviso Environmental Management System (EMS) for spill management and other environmental policies for any solvents, paints, or other liquids used through the course of onsite maintenance. Typically, solar photovoltaic transformers are dry type and contain no liquids. In specific cases where a liquid filled transformer is used (e.g. larger scale ground mount installations) an appropriate containment and spill response protocol shall be implemented (in conformance with EMS) on a site-by-site basis.

PV modules should only be cleaned with demineralized water and will therefore not require any management policies relating to flows or drainage off site. The maintenance contractor should ensure roof drains are clear and able to shed any excess water from cleaning prior to commencing cleaning products. See Section 6.3.1.6 for further guidance on module cleaning (e.g. process, frequency etc.).

Any controlled substances brought to site must be accompanied by a Material Safety Data Sheet (MSDS). These substances must be correctly labeled according to WHMIS.

3.5 Waste Management – Reuse, Recycling & Disposal

All requirements of the City of Edmonton Waste Diversion program shall be adhered to. Solar modules, inverters and other electronics are to be returned to the manufacturer or shall be recycled by a capable electronics recycling facility. Waste cardboard, plastic or other material shall be removed from site by the O&M contractor and reused or recycled where possible.

3.6 Reporting and Incident Investigation

If workplace injuries or illnesses occur, operations and maintenance staff have a duty to report/notify in accordance with the City of Edmonton Health & Safety Requirements. As such, employees are expected to report an incident to their supervisor within 24 hours.

3.6.1 Critical Injury or Death

Any injury must be reported, and notification provided to Alberta OH&S, as well as the joint health and safety committee. Based on this, the City of Edmonton will formally notify the Alberta OH&S as required. The notification shall outline the circumstances of the incident, as well as information as mandated in the Alberta OH&S Act. (e.g. section 18, 40 etc.).

In the event of a serious injury or death, the incident scene must be frozen for investigation until authorization has been given. No work shall be continued on site until such authorization has been given. Workers must comply with all requests regarding incident investigations. Investigations must comply with Section 40 of the Alberta OH&S Act.

3.6.2 Occupational Injury/Illness/Claim

If a claim for occupational injury/illness is made to the Worker's Compensation Board (WCISB) the employer must notify OH&S, the joint health and safety committee within 48 hours. This notification shall outline the circumstances of the incident as well as the information as mandated by Section 40 of the Alberta OH&S Act.

3.6.3 Potentially Serious Injury (PSI)

In the event of a potentially serious incident (PSI) that had the potential to cause serious injury or harm to a person at the work site then the City of Edmonton will formally notify the Alberta OH&S as required. The notification shall outline the circumstances of the incident, as well as information as mandated in Section 40 of the Alberta OH&S Act.
Workers must comply with all requests regarding incident investigations. Investigations must comply with Section 40 of the Alberta OH&S Act and notification provided to the joint health and safety committee. Recommendations from this investigation shall be submitted for review to the operational leadership teams.

3.6.4 Near Miss Incident

If an incident does not occur, if it is averted at the last minute, the systems and procedures involved shall be reviewed to determine the cause of the potential incident and means for ensuring that the situation does not occur again. Recommendations from this review in terms of engineering controls, administrative or personal protection equipment shall be submitted for review by the operations and the asset management team.

4 Personnel & Training

4.1 Personnel Classifications

To support the safe and reliable operation of the solar photovoltaic system it is necessary to implement layers of control to ensure the site access is managed safely:

- **General Public** – all equipment shall be controlled to prevent access by the public. This means ensuring fenced enclosures or lockable enclosures to prevent operation of switches or disconnects or other accessible equipment. An operations staff shall take measures while servicing a site to prevent unauthorized access, or erect warning barriers or signage where certain activities are taking place (e.g. live electrical testing etc.).
- **Facility Staff** – all facility operators shall be trained in the limits of approach, and extent of their responsibilities as they relate to the solar photovoltaic system. They are also the frontline representatives that will enforce site access, and control of hazardous areas (e.g. rooftop, electrical enclosures etc.).

- **Unqualified Personnel** – all staff accessing the site who may be providing non-solar related maintenance or operational supports shall be trained in the limits of approach, and responsibilities associated with servicing the building in and around the solar PV equipment. They will also be required to have qualified personnel accompany them while performing non solar related maintenance activities where those activities bring them to within the limited approach boundary (e.g. 1.0 m for 1000 VDC systems).
- **Qualified Personnel** – all staff qualified to work on the solar PV system shall confirm their understanding of the arc flash and shock hazards associated with the project (as documented within the Site Safety Data Sheet – SSDS). They shall hold all necessary certifications, safety training, and associated documentation (e.g. Working at Heights, etc.).

4.2 Qualifications & Certifications

Staff involved with the onsite maintenance activities shall be "qualified" to complete the work they are tasked with. Specific qualifications will depend on the nature of the task to be completed. The following types of staff will be involved:

- Licensed Electrician (with Solar Specific Experience)
- Certified Thermographer (minimum Level 1 based on requirements outlined by ANSI/ASNT CP-105 and CP-189 of the American Society for Non-Destructive Testing.)
- Certified Solar Technician Programs
    - Construction Electrician (NOC 7241) Solar Photovoltaic Systems Certified (SPVC) Certification
    - International Electrical Testing Association (NETA)
    - North American Board of Certified Energy Professionals (NABCEP)
    - North American Trade Association (NATS)
- Technicians or Technologists – Renewable Energy Specific Focus
- Professional Engineers – with discipline specific expertise.

Since solar is still an emerging industry, there are many highly qualified practitioners who may not have trained under conventional programs but are equipped to provide high value service. Similarly, there are staff trained through conventional means who do not have the specific solar or DC experience necessary to safely work on the systems. As such it is necessary to develop a means to validate training and experience in a consistent way regardless of credentials.

It is recommended that all facility staff, unqualified, and qualified personnel receive City of Edmonton specific safety training relating to the acceptable means of servicing their solar photovoltaic systems. Including but not limited to limits on testing, live work, and limited approach requirements.

4.3 Base Building Facility Maintenance Considerations

Facilities Maintenance Services (FMS) will typically manage maintenance requests through their dispatch SAP integrated platform. When preventative and corrective maintenance activities are scheduled and/or required, it is the responsibility of the solar maintenance staff to inform the required facility staff (if applicable) of their attendance and/or activities prior to arrival onsite.

Similarly, where servicing needs to take place on the roof or in and around the solar photovoltaic system equipment FMS or the Facility staff shall ensure activities are properly coordinated and qualified personnel are engaged with the work. This involvement could be to either supervise or to complete the work where work is to take place within the limited approach boundary to the solar equipment (e.g. servicing roof drains adjacent to solar modules).

4.4 Site Specific Orientation

While completing operations and maintenance services on a PV Array, the operations & maintenance staff (either internal, or sub-contractors) shall act as the prime contractor for the work. It is their responsibility to ensure that any of the contractor's staff, sub-contractors, other trades or building maintenance staff within the designated work area, have completed a site specific safety orientation. This safety orientation shall include review of the Site Safety Data Sheet (SSDS), review of all hazards, relevant safe work procedures, emergency response plans, site access and communication requirements. All personnel with access to the site are required to be fit for duty and qualified for the work required. Adherence to these requirements shall be documented via a tailboard form for each day of activities.

5 Operations

The operations role addresses primarily the activities that happen offsite and away from the physical solar photovoltaic system. The operations staff are typically monitoring system operation, and day-to-day production, addressing alerts, and/or scheduling either preventative maintenance (PM) or corrective maintenance (CM) activities.

5.1 Documentation Management

The City Operations team shall ensure that there is accurate information stored (as originally received by the installing contractor) in the CoE Document Management system, typical documents shall include:

- **Site Access –** ensure that current and relevant site access information is accurate for the site.
- **Drawings** - All drawings specific to the site should be retained, specifically for the Single Line Drawing (SLD) and as-built Array layout complete with stringing diagram, or optimizer/microinverter layout. Where applicable all record drawings shall have been authenticated by an EoR licensed through APEGA.
- **Equipment Manuals** – Electronic copies of equipment manuals shall be retained on a shared digital archive accessible to field and office staff. Hardcopies (if provided) should be retained onsite for access by field staff.
- **Spare Parts / Replacement Parts** – a list of stock spare parts, and model numbers for replacement parts (including circuit breakers, fuses, inverters, modules etc.).
- **Warranty Information –** records of initiation date on warranties, and duration of warranties shall be maintained (as provided by the Asset Management group) to ensure Return Merchandise Authorization (RMA's) can be processed in a timely manner.
- **Maintenance Logs –** logs of historical servicing, repairs, and revisions to the system shall be maintained to assist in identifying longer term trends.
- **Maintenance Reports –** prior Preventative Maintenance and Corrective Maintenance reports.
- **Test Data –** baseline test results from initial commissioning, as well as any field test data, (e.g. infrared images, string testing results etc.) taken through the course of maintenance activities.

5.1.1 Revision Control & Versioning

The documents will need to be updated from time-to-time as changes are made or variations from the as-built documents are identified onsite. It is important to track these changes, and when the changes or issues were identified. As the project is operated, the expectation is that the operations team will maintain a record of any variations identified in the documents from the onsite conditions. It is recommended that on no less than an annual basis, these changes are added to the record documents maintained by the CoE. All major system changes will be managed as separate projects and shall also include the provision of as-built drawings in accordance with *Volume 2 - Design Guideline*, and *Volume 3 – Construction Guideline*.

5.1.2 Digital Access

All documents shall be accessible through Google Drive setup for the express purpose. The organizational structure should be setup on a project-by-project basis, with information on the sites readily accessible to all staff. Dynamic information such as site access and contact personnel shall be maintained in a format that can be readily accessed by staff or resources both within and external to the City of Edmonton.

5.2 Remote Plant Monitoring and Reporting

As detailed within the design and construction guidelines (Volume 2 & Volume 3) each of the solar photovoltaic systems will be monitored via two different platforms:

- **Inverter OEM Monitoring Platform** – this is the primary means for validating day-to-day operations by facility monitoring staff. This platform will be used to identify system outages (partial or full), alerts and warnings (e.g. arc faults, or inverter level warnings) and for diagnostic investigation of issues prior to mobilizing a field team. It is expected that this will be the primary monitoring platform for the operations team.
- **BAS Energy Metering** – the secondary platform for validating system performance will be a Building Automation System (BAS) integrated metering platform that will integrate with existing facility consumption metering infrastructure. It is expected that this energy data will be used to benchmark system performance across longer time periods (e.g., months or quarters) to identify larger trends. It is expected that this will be the primary monitoring platform for the solar asset management team.

Technical Rationale

This data will be integrated into the energy management platform that will be evaluating consumption data (since these are microgeneration assets, they will be offsetting energy use behind-the-meter and as such the solar generation data is a key attribute of evaluating facility performance.

It should be noted that access to both systems is recommended for the operations and the asset management groups so that they can validate results on one platform against the other. This can be valuable for identifying issues around short term outages (e.g. inverter portal may go down, but BAS metering confirms the solar PV system is still operating) or for understanding concerns around underperformance (or overperformance) as the case may be.

5.3 Remote Sensors Validation

Sensors installed onsite to measure irradiance and temperature shall be checked compared to online reference datasets (e.g. Clear Sky, Environment Canada) or sites in proximity with similar conditions.

5.4 Configurable Alarms

Where possible, alarms on the Inverter OEM monitoring system shall be setup to alert the operators to abnormal conditions. These alarms shall be email notifications – the specific type will depend on the Inverter OEM platform. Alarms that should be considered include:

- Inverter outage (>24hours)
- System Outage (partial or full)
- Production discrepancies (where the monitoring system can benchmark generation).
- Protection controls (e.g. AFCI, Over/under Voltage, Over/Under Frequency, Anti-Islanding etc.)

Alarms shall be tested as part of the annual maintenance visit. This can be done by simulating outages (through the isolation of the system or portions of the system).

5.5 Data Analysis

The operator will be responsible for assessing data on a daily and weekly basis, identifying short term trends that could indicate system outage or issues. This data will largely be evaluated through the Inverter OEM portal and would not include external production benchmarking (that is being handled by the asset management team). System status shall be monitored, and alerts shall be investigated as they arise.

Production benchmarking will be completed by the solar asset management team and will be focused on validating production (normalized for recorded insolation and temperatures) to determine if there are system wide inefficiencies that need to be investigated and resolved.

5.6 Event Records

All monitoring events shall be recorded and logged (either using the existing SAP infrastructure, or other existing CoE platform). The log shall include action taken, outcome, and follow-up if required (either remotely or onsite). Events shall be recorded even if they do not result in a mobilization onsite to ensure that recurring events can be tracked and addressed if they seem to persist.

5.7 Ticketing System

All events that are elevated to a service call, or investigation onsite shall be ticketed using the SAP integrated platform, and a prioritization assigned (as noted above). This ticketing shall include the nature of the call, team that was dispatched, expected timing, and results of the dispatch. Records around when the ticket was initiated, addressed, and issue resolved shall be tracked to inform the Key Performance Indicators (KPI's) for field teams.

5.8 Incident Response

The monitoring program should include at a minimum a twice daily remote review (morning and late afternoon) of the inverter level monitoring system to identify faults, system outages, or other concerns. It is not advisable to rely on email generated responses alone (although they can be a useful tool) as monitoring systems and alert thresholds are subject to change and can result in issues or concerns being overlooked.

When an issue is identified it is important to log the incident, and rank or classify it to ensure that an effective and measured response can be taken.

Table 2 – Incident Response Levels

Classification	Nature of Issue	Response Required
Emergency	Safety, Fire, etc.	Emergency service call (after hours or weekends) and potentially first responders.
Urgent	System Outage (>150 kW) or full communications outage	1 to 2 business day turnaround
Medium	System Outage (<150 kW) full or partial system outage	2 to 5 business day turnaround
Low	Little to No Safety or Production Impact	Next scheduled maintenance

The specific approach and classification will need to be tailored to the context of the site. A site that is showing recurring faults of a specific type (i.e. arc fault trips) may require more investigation to get to the root cause. It is highly recommended that the root cause analysis is undertaken by an engineer, technician, or field electrician with experience in tracing faults, and resolving issues.

Any major faults (e.g. catastrophic inverter failure, or damage to equipment) shall be investigated by an independent engineer or contractor not directly involved in the construction or maintenance of the facility. This third party shall be provided all the record documents for the site, as well as any historical PM, CM, or related reports.

5.9 Event Documentation

A site monitoring log should be maintained (either as part of the O&M log or in a related spreadsheet) to track service interruptions and note concerns that should be monitored, or where further investigation is required. Where practicable it may be necessary to connect with a facility operator or site contact to ascertain the state of the system prior to mobilizing a field technician – in all those cases the correspondence and response shall be logged through the SAP integrated platform.

5.10 Operations Team input to Quarterly Reports

There are a number of inputs from the operations team that are to be provided to the solar asset management team to prepare quarterly reports including:

- **Activity Summary** – indication of the maintenance performed during the preceding month (both directly by the O&M contractor, but also by any designated sub-contractors).
- **Spare Parts Inventory** – indicating the spare parts used during the preceding month, and stock remaining on any project specific allocated inventory. Including what consumable parts are stored onsite, and what parts the contractor is expected to stock in their service vans.
- **Technical Issue Log** – indicates technical issues identified in the previous month, along with any outstanding issues (including duration of the issue and anticipate date of resolution) and planned remedies.
- **Outage Log** – indicates the outages that occurred in the preceding month - including duration, cause, and whether they were scheduled or unscheduled. This log will identify the amount of time and cause for the outages. Including downtime due to maintenance, manufacturer's responsibility, the Owner/utility responsibility, or other conditions.
- **Inverter Comparison** – this breakdown will list inverters and the respective generation relative to each other.
- **Health & Safety Log** – will indicate health and safety issues encountered within the preceding month.
- **Equipment Calibrations -** lists any equipment that has been calibrated in the preceding month. Data shall include device type, manufacturer, model number, serial number (if applicable), calibration date and any relevant notes provided with the calibration report.
- **Service Report & Photo Record –** reference will be made to any documentation/photos based on the prior month's activities, including preventative maintenance, corrective maintenance, or emergency call-outs. The monthly report template will include reference/links to separate site reports.

5.11 Data Security & Integrity

The monitoring system and its associated components shall adhere to the firewall and cyber security policies established by the City of Edmonton IT department. It is noted that Supervisory Control and Data Acquisition (SCADA) systems require an additional level of security to ensure remote control of sites by unauthorized operators does not occur.

5.12 Key Performance Indicators

5.12.1 Performance Ratio

The performance ratio represents the end-to-end efficiency of the system – from solar irradiance (or insolation) in and power (or energy) out. The power (kW) portion of this equation compared to onsite irradiance is something that can be tracked on a day-to-day basis and should be a key focus of the operations monitoring team. The energy

(kWhr) component compared to insolation (W/m^2) during the same time is something that should be benchmarked by the solar asset management team.

5.12.2 System Availability

Records should be tracked for system availability. Outages whether scheduled or unscheduled shall be logged, and where possible lost generation should be estimated (either based on similar inverters operating, or irradiance onsite based on standard performance ratios). This is important so to ensure that benchmarking (whether quarterly or annual) takes into account all unavailability and it is not mistaken for a generalized under performance issue.

5.12.3 Response Time

The dispatch and ticket tracking should include metrics associated with identification of an issue, dispatch request, and resolution to evaluate the performance of differing field service teams, and to inform the optimization of the monitoring and corrective maintenance program.

6 Maintenance

6.1 Annual Maintenance Plan

Based on the operations & maintenance documentation provided by the contractor, the solar asset management team shall review and prepare a site specific annual maintenance plan for the project. This plan should be tailored to address the specific equipment onsite (e.g. manufacturer specific requirements). This plan can be used for scoping the preventative maintenance work for CoE staff and/or tendering that work to a sub-contractor.

6.2 Preventative Maintenance

Preventative maintenance shall be scheduled so that a given system is serviced around the same time of year on an annual basis to permit year-over-year comparison in test results on outcomes. Where possible these schedules should be identified (by the given month and week, not day as weather conditions may dictate rescheduling) so that operators and maintenance staff can properly plan. Where low grade issues have been identified in the preceding periods, the workorders for the PM visit should be amended to reflect the site specific conditions.

6.2.1 Notification & Approvals

The field team shall ensure that the facility operator and City of Edmonton operations coordinator is informed of all activities involving mobilization to site. Where schedule changes may occur, all parties shall be kept informed. Where site specific orientation, or training is required (e.g. relating to roof access, site access, or other mitigating circumstances) all documentation associated with those approvals shall be submitted no less than 48 hours before the scheduled visit.

6.2.2 Site Visit Expectations

Field technicians are expected to arrive onsite with a comprehensive understanding of the scope of work (e.g. work orders are to be based on contractual maintenance requirements and amended to address site specific conditions). They shall be equipped with all the necessary tools, equipment, and PPE. Failure to be properly equipped or provisioned for the scope of work shall be a cost borne by the contractor (assuming field work is sub-contracted) and not the CoE.

6.2.3 Roof Access

Roof Access should be provided wherever possible via a pre-existing roof access hatch/ladder. If no permanent roof access exists, it is permissible to use a temporary ladder provided all parts of the ladder safety protocol are followed. If at any time the employee feels unsafe in any regard to the access, they must refuse to use the access

method, and shall notify management so that the situation can be investigated and where required a safe means of access can be provided. For roofs without permanent roof access, it is expected that service technicians would use a lift for any situations where the roof is higher than a **9 m (30 ft)** extension ladder properly placed can reach, and/or a working platform sufficient for safe servicing of the array is required.

6.2.4 Delivery, Storage, and Handling of Products

It is recommended that the maintenance contractor has a proper complement of consumable parts (e.g. fuses) to provide ready access to replacement parts and components without requiring additional trips to site. For more major equipment such as replacement modules, optimizers, or inverters it is expected that the City of Edmonton will maintain that inventory at a central location. The specifics of this inventory will develop as additional projects are deployed and surplus parts (e.g. modules, fuses, etc.) are collected.

6.3 Annual Review, Testing, and Maintenance

6.3.1 Site Condition Visual Review

One of the most valuable techniques for identifying existing problems and preventing future problems is to walk the site and conduct a thorough visual and hands-on inspection of the PV system components. These inspections should be conducted at regular intervals, and personnel should use checklists developed for these periodic maintenance activities (refer to separate site/equipment review checklists) to ensure that the inspections are thorough and complete.

Where employees are involved in visual reviews of sites, they are to be sure not to touch live or potentially live connections (even with proper PPE), and the opening and exposing of conductors/terminals shall be undertaken only by qualified personnel.

Safety Comment

It is highly recommended that all field staff work in teams of at least two (2) people. This will ensure that should an issue arise, there will be someone else on hand to aid in the intervention, or direct emergency rescue personnel to the location.

6.3.1.1 General Site Annual Inspection

At least once a year (for larger system consider twice yearly visits), field technicians shall conduct a general inspection of the PV installation site. During this inspection, technicians shall:

- ensure roof penetrations are watertight, if applicable.
- ensure roof drainage is adequate, roof drains are not clogged, and confirm that there are no signs of water pooling in the vicinity of the array;
- check for vegetation growth or other new shade items such as retrofitted rooftop equipment etc;
- check for ground erosion near the footings of a ground mount system;
- confirm proper system signage is in place and has not been damaged or inadvertently removed;
- confirm appropriate expansion joints are used where needed in long conduit runs;
- confirm electrical enclosures are only accessible to authorized personnel, are secured with padlocks or combination locks, and have restricted access signage;
- check for corrosion on the outside of enclosures and the racking system;
- check to ensure fasteners on racking and equipment are properly torqued and secured;
- check to ensure the array has not shifted, or dislocated any ballast (for module or inverter supports).
- check for cleanliness throughout the site—and clean where required
- check for loose hanging wires in the array; and
- check for signs of animal infestation under the array.

6.3.1.2 Roof Maintenance

The solar contractor is not specifically responsible for roof maintenance and any activities relating to the roofing system shall be coordinated with the roofer that holds the warranty for the project. The solar contractor shall notify the facilities operator so that appropriate action can be taken. These types of activities may include:

- **Visual Review** – if portions of the roof system are experiencing ponding, or accelerated degradation these should be noted and forwarded to the City of Edmonton facilities staff.
- **Vegetation Management** – where the root system is embedded in drains, seams, or associated roofing materials a strategy to remove the vegetation shall be implemented to ensure the integrity of the roof is not compromised.
- **Drain Servicing** – where drains are clogged or backed up and simply removing collected debris is not sufficient.
- **Seam Sealing** – where seams appear to require additional maintenance, the solar contractor shall inform the facilities operator. Where seams are near the solar array, coordination between the respective contractors will be required for safe and appropriate servicing.
- **Array Infrared Imaging** – if Array Infrared imaging reveals excessive moisture in and around the roof system this should be noted for remedial action by the facilities maintenance team.

In general, the solar contractor shall not directly undertake any maintenance activities on the roofing system without the specific direction from the City of Edmonton roofing warranty holder.

6.3.1.3 AC and DC Visual Review

The installation should be inspected regularly for issues that impact the physical integrity or performance of the PV system. A visual inspection should include the following actions:

- Inspect the inverter/electrical pad to make sure it does not show excessive cracking or signs of wear. The inverter should be bolted to the pad at all mounting points per the manufacturer installation requirements. Depending on the size, location, and accessibility of the system to unqualified personnel, the inverters, combiner boxes, and disconnect switches should require tools or have locks to prevent unauthorized access to the equipment.
- Look for warning placards including arc flash or PPE requirements for accessing equipment. Be sure to comply with all warning placards. If no placards are present, or if some placards are missing, make a note of it and install the missing placards during the maintenance visit.
- Inspect PV modules for defects that can appear in the form of burn marks, discoloration, delamination, or broken glass.
- Check modules for excessive soiling from dirt buildup or animal droppings. (See section 6.3.1.6 for proper procedures for cleaning an array.)
- Ensure that the module wiring is secure and not resting on the roof, hanging loose and exposed to potential damage, bent to an unapproved radius, or stretched across sharp or abrasive surfaces.
- Inspect racking system for defects including rust, corrosion, sagging, and missing or broken module clamps, bolts or other hardware.
- Inspect racking frame and ballast to identify any areas of deterioration, damage, or missing elements
    - Cracked or damaged ballast is to be replaced
- Annual torque testing of (sampling 10% of connections) to ensure no loose connections
- Inspect conduits for proper support, bushings, and expansion joints, where needed.
- In roof-mounted systems, check the integrity of the penetrations.
- In ground-mounted systems, look for signs of corrosion near the supports.
- Open Inverters (or combiner boxes) and check for torque marks on the connections. Torque marks are made when lugs have been tightened to the proper torque value. Ideally, they are applied during initial installation, but if not, the technician can mark the lug after torqueing during a maintenance visit (Refer to *Volume 3 – Construction Guideline* section 5.8 for torqueing requirements). A proper torque mark is made

with a specialized torque marking pen. The mark is a straight line through the lug and the housing. Over time, if the line separates between the lug and the housing, it shows that the lug has moved and needs to be re-torqued.

- Look for debris inside the enclosures and any evidence of water intrusion. Look for discoloration on the terminals, boards, and fuse holders.
- Open the door to the disconnect(s) and look for signs of corrosion or damage. Check to make sure the cabinet penetrations are properly sealed and there is no evidence of water ingress. Check for torque marks on the terminals.
- Perform a visual inspection of the interior and exterior of the inverter. Look for signs of water, rodent, insect, or dust intrusion into the inverter.
- Check for appropriate torque levels (via visual or otherwise) on the field and factory terminations.
- If a weather station is present, ensure that the sensors are in the correct location and at the correct tilt and azimuth. A global horizontal irradiance sensor should be flat, and a plane of array irradiance sensor should be installed to the same pitch and orientation as the array. Irradiance sensors should be cleaned to remove dirt and bird droppings

6.3.1.4 Manufacturer-Specific Inverter Inspection

Each inverter manufacturer will have specific requirements for inspection, testing, services, and documentation to meet its warranty obligations. Typical requirements for inverter inspections include:

- Record and Validate all voltages and production values from the human-machine interface (HMI) display.
- Record last logged system error.
- Clean filters (review manufacturer requirements for filter replacement).
- Clean inside the cabinet.
- Test fans for proper operation.
- Check fuses to ensure continuity and condition.
- Check torque on terminations.
- Check gasket seal and observe and address any water infiltration.
- Confirm warning labels are in place.
- Look for discoloration from excessive heat buildup on any parts or components (specifically capacitors and connection points).
- Check for any paint chipping or corrosion (and address if practicable while onsite)
- Check integrity of lightning arrestors.
- Check continuity of system ground and equipment grounding.
- Check mechanical connection of the inverter to the wall or ground.
- Check internal disconnect operation.
- Verify that current software/firmware is installed.
- Document findings both good items, items that need to be addressed and for all work performed.

6.3.1.5 Housekeeping and Cleaning

Housekeeping shall be undertaken where the needs arise on both the annual and semi-annual visit. This shall include (but may not be limited to) cleaning of inverter equipment, heat sinks, fan shrouds etc. as well as cleaning (dry or with a mild spray) the inside and wiring compartments. A non-conducting vacuum should be used inside any live compartments and staff shall be properly gloved (with the appropriately validated electrical gloves).

Module washing is not typically included in this – however if there are one or two modules that are severely soiled, they should be cleaned prior to any production testing. More extensive soiling may require coordination with an approved module cleaning company and should be quoted and treated as a corrective maintenance activity.

6.3.1.6 Cleaning of Modules

Where module cleaning is required as part of the maintenance plan, cleaning procedures should follow the module manufacturer installation manual. Cleaning is recommended to be on a bi-annual basis (or as stipulated within the asset management maintenance plan), and for lower slope arrays (<7°) consider annual cleaning. This will prevent the accumulation of soiling along the bottom edge of the module which can lead to long term performance issues, and potentially damage the modules. Specific approach shall be at the direction of the Asset Management Team.

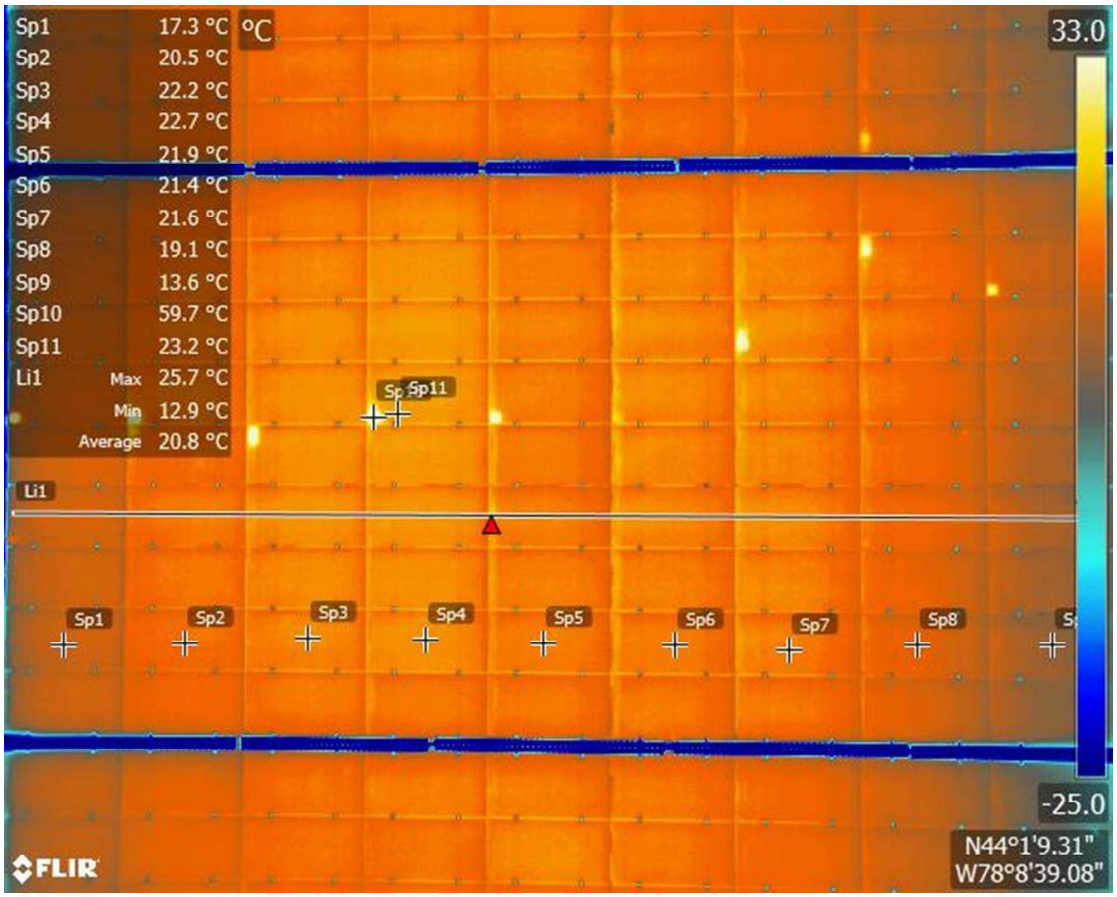


Figure 3 – Bottom Edge (left side) Soiling Leading to Overheating cells and lost energy

De-mineralized water should be used. Do not use soap, harsh chemicals, or other cleaners on the modules as this could leave behind residues or damage the surface of the module. Do not spray cold water directly onto hot solar modules. Schedule work for early or late in the day to minimize temperature extremes. If using water to clean modules, it is best to do so on overcast days. Ensure any cleaning appliance is soft (e.g. microfibre brush) and does not scratch the surface of the module (never use a squeegee or rubber scraper). It is recommended to use a soft cloth or a solar specific cleaning brush. Avoid cleaning modules with water at times of year when temperatures may drop below zero degrees Celsius within 72 hours. Ensure any roof drains are clear of buildup for shedding of excess water.

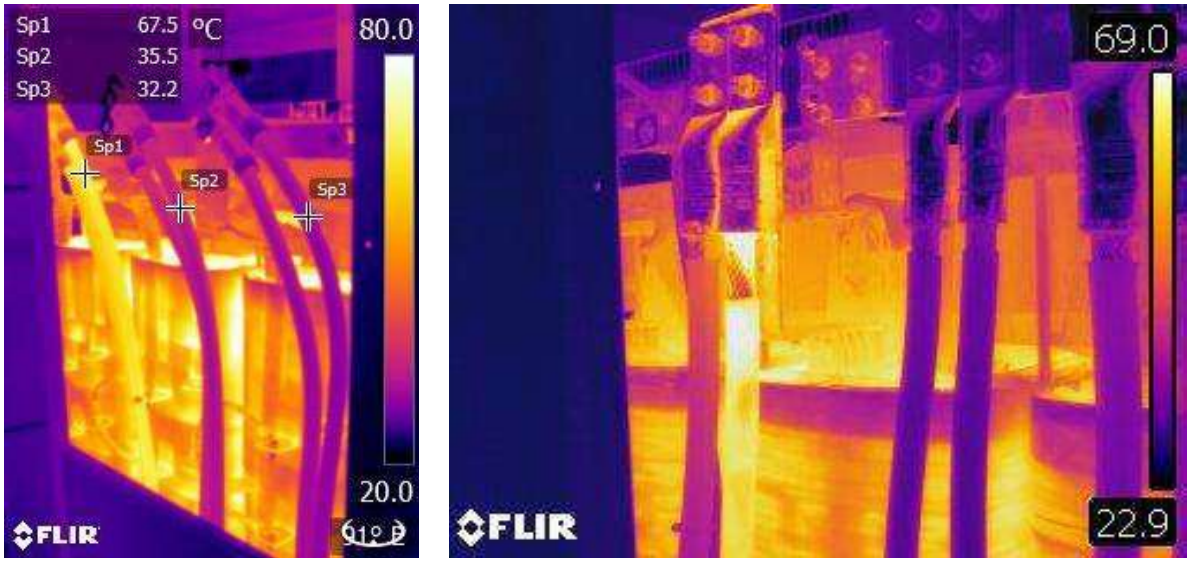
6.3.1.7 Minor Repairs

Where practicable minor repairs shall be undertaken and completed while staff are onsite. The general rule of thumb is that provided the repair can be completed in under 15 minutes, and for less than $100 it is preferable to have the repair addressed while the team is mobilized (and avoid additional travel/truck charges). Should an issue be identified that is more extensive – it should be documented, and a quote generated for the operations (and/or asset management) team to decide on if and when to proceed with the work.

6.3.1.8 Infrared Survey of System

Infrared (IR) imaging on the solar photovoltaic equipment – both AC & DC are an integral part of the preventative maintenance program. Specific care and attention should be given to ensure IR imaging takes place when the conditions are right. Please refer to *Volume 3 – Construction Guidelines PROTOCOL 6* for specific infrared imaging test procedures.

The infra-red imaging inside of live electrical equipment is one of the highest risk activities associated with solar photovoltaic maintenance. However, there are a number of steps that must be taken to manage that risk. All staff involved in IR Imaging shall make use of the aforementioned PPE associated with the exposure classification of the equipment.



Left Image: Benchmark IR of 600V connections during commissioning identified faulty ACWU90 cable on L1 (manufacturing defect)

Right Image: same transformer -480V connections, show failing crimp on L1 (it is important to note that this crimp passed the commissioning benchmark IR 3-years prior).

Figure 4 – Solar PV System Infrared Imaging - Step Up Transformer

The infra-red imaging taken shall be provided for all stages of imaging and records of the raw digital images, and processed images (e.g. tuned for conditions such as reflected temperature, environmental conditions, and calibration) shall be provided in the preventative maintenance report.

Any anomalies identified during the imaging should be addressed (where possible) during the visit through the tightening of connections (when the system is again de-energized) or other appropriate intervention. Photos following any remedial activities should be taken when the system has reached an appropriate operating temperature to demonstrate the identified issue has been resolved.

6.3.1.9 Review of Monitoring System Sensors

This review should happen annually, it should include a visual review of possible damage to the sensors, wiring leads (or wiring harness) mounting system (e.g. Fixed, or adhesive) and data aggregator. Where possible voltage/current measurements should be recorded with notation of a reference temperature or irradiance to ensure that sensor calibrations are not out of alignment.

6.3.2 Maintenance Reporting

A key part of managing and maintaining a system is tracking activities onsite, as issues arise, and corrective action is taken. It is important to trace trends and develop a systematic approach to identifying persistent issues and resolving them. To this end it is expected that the following reporting will take place:

6.3.2.1 Site Visit Reports

Site visit reports should be completed for all service calls whether for preventive or corrective maintenance. The basic information that should be included are:

- Site Name (with Building ID)
- Date of Visit (and Date of Report)
- Personnel Onsite & Reviewing Report
- Purpose of Visit
- Outcome of Visit
- Actions Taken
- Recommendations (e.g. further investigation, or repairs etc.)

This information should include both issues, but also activities completed, and items that are in good working order (i.e. do not just report problems). This documentation shall be kept on the project file and used for future visits.

6.3.2.2 O&M Record Log

A digital log (via the SAP integrated platform) shall be maintained to identify the activities onsite, who accessed the site, any modifications made and corrective action to be taken following those activities. Each of these entries should be supported by a site visit report (e.g. preventative or corrective maintenance) as well as resolution/follow-up. Where activities are being jointly managed by the City of Edmonton and a sub-contractor all parties shall have read/write access to the file to ensure actions taken onsite are properly coordinated and recorded.

6.4 Corrective Maintenance (CM) Reporting

All activities onsite shall be accompanied by a corrective maintenance report that contains the basic information required by Section 6.3.2.1 Site Visit Reports. However, it should also include photographs illustrating the condition prior to the repairs, and the photographs once the repairs were complete.

6.4.1 Diagnostic Testing

When faults occur, it is recommended that someone attends site in relatively short order to visually ascertain the conditions onsite. Care should be taken to ensure that any faults are identified and resolved prior to attempting to re-energize the system (in whole or in part).

6.4.1.1 LEVEL 1 – Low Risk - Non-Contact (Visual / External IR)

First stage is to review the system and identify the source of the issues. Non-contact approaches such as Infra-Red imaging (in the array) and visual review of components is an important place to commence any investigation. All portions of the array and equipment associated with the fault shall be reviewed prior to commencing any more detailed testing. This is an important step to ensure there are no other visible factors that could make proceeding unsafe or unreliable.

6.4.1.2 LEVEL 2 – Minimal intervention (Non-Operating Tests)

The next stage of investigation requires the testing of the system in a non-operational state. This could include verifying continuity, megger testing conductors, IV curve tracing (for DC strings) and so forth in an effort to pinpoint the source of the fault and remediate it. Once all avenues of investigation with a non-operating system have been exhausted, the next stage is to validate during operation. *NOTE: even if a perceived cause is discovered, it is best to assume that other faults may still be present in the system and to proceed with the utmost caution.*

6.4.1.3 LEVEL 3 – Operating Verification

This stage involves taking readings of the system while operating. This is the highest risk as a fault could still be present, and typically to acquire data (e.g. IR imaging inside enclosures, clamp ammeter readings etc.) requires equipment enclosures to be open representing the highest arc flash and shock hazard. Equipment that has been opened for testing shall only be energized remotely.

6.4.2 Root Cause Analysis

Where a fault occurs on the same site or impacts similar systems it may be necessary to undertake a root cause investigation. Depending on the nature of the issue, this type of investigation may be required to be conducted by a specialized contractor, or engineering consultant in order to get an independent perspective. A plan structured to address the most likely causes shall be provided by the contractor or consultant prior to commencing any work.

6.4.2.1 Safety Issues

Safety issues shall be investigated as soon as practicable and corrective action taken to resolve any specific situations. Facility operators shall be informed of the nature of the risk and where necessary systems shall be isolated and not operated until the situation can be fully assessed.

6.4.2.2 Production Issues

Production issues are typically not as critical from a safety perspective, and typically develop over longer time lengths (with the exception of obvious equipment or component failure) as a result the specific strategy to investigate may require longer term monitoring, site specific testing and verification beyond the standard maintenance activities.

7 Conclusion

The operations & maintenance program shall be coordinated by the Solar Asset Management team, and specific parameters around the activities to be undertaken are defined within the City of Edmonton *Solar Photovoltaic Program Volume 5 Asset Management Guideline*. It is expected that the specific requirements of this standard will be jointly enacted by both City of Edmonton staff and their designated sub-contractors. Any activities impacting the long term performance, or durability of the project should be brought to the attention of the Solar Asset Management team to ensure the maintenance plan for the specific site can be tailored to suit its needs.

SCHEDULE 1 – Site Documentation

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

☐ **Site Access Documentation**

☐ **As-Built Drawings**

- Single Line Diagram (SLD)
- Array Layout (stringing)
- Equipment Locations

☐ **Equipment Manuals (Major equipment)**

- Modules
- Racking
- Inverter
- Module Level Power Electronics (MLPE)

☐ **Parts List**

- Fuses
- Breakers
- Etc.

☐ **Baseline Test Results**

- Megger Testing
- IV Curve Tracing
- IR Imaging

SCHEDULE 2 – Site Access Information

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

Location

INSERT SITE PLAN

System Owner Contacts

System Contact #1	Name:	*INSERT NAME*	Email:	name@edmonton.ca
			Address:	123 Example Road
	Department:	*INSERT DEPARTMENT*		Edmonton, AB

	Phone: Cell: *INSERT PHONE NUMBER* Fax:	
	Primary contact:	
	Secondary contact:	

Site Access Instructions

Day Prior to Arrival:

- Notify *INSERT PRIMARY CONTACT* by email
- Notify *INSERT SECONDARY CONTACT* (see contact information below) by email the day before conducting any visits to site

Facility Manager	Name: *INSERT NAME* Department: *INSERT DEPARTMENT* Phone: Cell: *INSERT PHONE NUMBER* Fax:	Email: name@edmonton.ca Address: 123 Example Road Edmonton, AB

Upon Arrival:

- Sign-in at reception located in the front lobby
- If required, sign and submit “Safe Roof Access Policy” for any new field staff employees

Access Details:

- *INSERT SITE SPECIFIC ACCESS DETAILS*
  - *Ladder requirements*
  - *Array Access requirements*
  - *Equipment Locations*

Before leaving:

- Lock up all equipment, both fenced enclosures and the roof access ladder
- Sign-out at reception
- Send an email to *INSERT PRIMARY CONTACT* notifying them that staff have left site
- Check Monitoring Portal (*INSERT LINK*) to ensure that the system is fully operational:

  Username: XXXX
  Password: XXXX

Other

Insert any additional site specific considerations