Loss Prevention Standards – Asset Class(es)

Ground Mounted Solar Photovoltaic Systems – Construction

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Ground mounted solar photovoltaic (PV) systems are exposed to a number of hazards during the construction phase.

This Loss Prevention Standard outlines the main risks and provides useful guidance on reducing the risks of loss or damage during the installation phase and ensuring the solar PV system is resilient and constructed to a good standard.

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Ground Mounted Solar Photovoltaic Systems – Construction

Introduction

Ground mounted solar photovoltaic (PV) systems are a common sight in many countries across the globe. This is a growing sector with the International Energy Agency predicting solar PV will account for around 80% of the 5500 gigawatts of worldwide renewable energy capacity constructed between 2024 and 2030. The energy generated is typically sold to national power suppliers but can also be stored and used locally to support community and/or industrial power requirements.

With global climate change leading to extreme events including windstorms, wildfire, flooding and other natural catastrophe events, notwithstanding the more common fire, accidental damage and general wear and tear incidents associated with poorly installed systems, it is critical solar PV systems are planned, designed, installed, tested and commissioned to a high standard and to be as resilient as possible.

This document provides useful guidance on constructing ground mounted solar PV systems to a standard that reduces the potential for loss or damage.

Note: This document is not intended to address roof mounted solar PV systems, although dedicated Loss Prevention Standards for such systems are available, nor Liability exposures. The presumption is that all regulatory requirements, Fire Risk Assessments, and compliance with requirements placed by the local authority having jurisdiction which would include licencing, building permissions, regulations, codes, or standards, have or will be met.

Understanding the Risks

The risks of damage to ground mounted solar PV systems relating to the construction phase include:

- **Windstorm.** Systems in the course of construction, temporary work and poorly installed systems are more vulnerable to high wind conditions. This can include forced removal of panels/modules that have not been fully torqued, weakening of joints, strain and stresses to supporting framework and foundations, tension and damage to cabling. Unsecured items, stored materials and equipment etc., can also become windblown and cause damage.
- **Fire.** Potential causes of fire damage include:
  - ✓ **Malicious.** Deliberate ignition/arson including civil unrest events from opportunist trespassers.
  - ✓ **Electrical.** Damaged, incomplete and/or faulty electrical components and equipment, shorting and overloaded systems can lead to ignition within connectors, junction boxes, panels, inverters and other electrical equipment including sub-stations and transformers.
  - ✓ **Hot works.** Poorly managed hot works during the system installation e.g. cutting, brazing, welding, grinding etc., can ignite dry vegetation and combustible materials including plastic solar PV system components.
  - ✓ **Smoking.** Discarded smoking waste can ignite contractors waste, stored materials and dry vegetation.

  The potential for fire growth and spread directly relates to the fire load, e.g. the amount of combustible materials at the site including panel components, plastic covered cabling, cable reels, packaging, dry vegetation etc., which would support fire growth. As such, combustible materials should be adequately separated.
- **Flooding.** Excessive rainfall or rising groundwater can infiltrate substation and transformer cable pits potentially damaging electrical equipment, underground cable conduits can be breached leading to electrical faults and deterioration of cabling. More severe incidents can lead to significant structural damage to the installation, access roads and other infrastructure.

- **Security.** Construction sites are vulnerable to theft and ground mounted solar PV sites are particularly exposed given the often rural and isolated locations, lack of manned security outside of working hours, including weekends and extended holiday periods, theft attractive equipment e.g. panels, cabling, tools and their relative ease of removal.

  Refer to Aviva Loss Prevention Standards – **Ground Mounted Solar Photovoltaic Solar Farms Security** and corresponding **Ground Mounted Solar Photovoltaic Solar Farms Security Checklist** for guidance on securing solar PV sites, including during the construction phase.

Managing the Risks

General Planning and Design Considerations

- Ensure competent and experienced system designers are utilised.
  - ✓ All consultants and contractors should be reputable and experienced in solar PV system design and installation projects.
- Ensure compliance with any national or local regulations and accreditation requirements.
  - ✓ In the UK, and recognised in Europe, the installer should be certified under the Microgeneration Certification Scheme (MCS) by an appropriate UKAS nationally accredited body.

    Note: MCS certification is a requirement for United Kingdom installers for installations up to 50kW, and whilst this is significantly below the power generating capacity of a large solar PV installation, it does provide a quality based framework for contractors.

  - ✓ UK construction work is likely to be subject to the Construction, Design and Management (CDM) Regulations, which places duties on various parties involved in the construction project e.g. owner, designers, and contractors, to manage the risks associated with construction work.
  - ✓ Other international standards to consider include:
    - North American Board of Certified Energy Practitioners (NABCEP) certification.
    - Solar Energy Certification (SEC) – Europe.
- The design specification should take into consideration the site conditions for existing, temporary and permanent drainage requirements, temporary loading for foundation and erection works.
- Pre-qualification design assessment procedures should be in place to ensure the planned works align with the agreed design specifications.
- Procedures should also be agreed in relation to quality control, materials verifications, site acceptance and testing of equipment, collating and verifying certificates of conformity etc.
- Ensure appropriate smoking and setting down and storage locations are provided, at least 10 metres from the works and other valuable assets.
- Hot works should be controlled in accordance with Aviva Loss Prevention Standard **Hot Work Operations.**
  - ✓ Thermographic cameras should be incorporated into fire watch procedures to help identify hot spots, heat transfer etc. Refer to Aviva Loss Prevention Standard **Thermographic Surveys** for further guidance.

Ground Conditions

The quality of the ground conditions at the site are integral to the structural resilience of the solar PV system.

- A detailed interpretative ground investigation report is critical to support the foundation design, construction of access roads, any temporary works including piling or lifting mats and mitigate environmental risk factors including surface water and groundwater flooding. Any comprehensive report should include:
  - ✓ Intrusive sampling and logging of underlying ground conditions utilising boreholes, window sampling and trial pits.
  - ✓ Soakaway or other suitable in-situ permeability test.
  - ✓ Groundwater analysis to determine natural fluctuations in water depth and acidity.
  - ✓ In-situ and laboratory testing to include classification and particle size analysis, permeability, and appropriate strength and compaction testing for all identified soil types.
  - ✓ Environmental assessments including soil and water testing for contaminated or hazardous ground, peat extraction etc.
  - ✓ Where necessary, additional investigations including monitoring of installed gas and groundwater for environmental risks.
  - ✓ Utility investigations to identify the presence of existing infrastructure.
- **Peat Load.** High peat content can affect soil stability, increase water retention and create surface conditions with high moisture, which can affect the pH balance and complicate the use of concrete foundations. There are also likely to be planning permission challenges due to the associated emissions of disturbing peat.

Foundations

PV system foundations are typically piled e.g. poles and beams driven or screwed into the ground, and typically used on normal soil conditions, or pad e.g. cast-in-situ concrete slabs or ballasted blocks which are designed to be used where the ground is impenetrable.

- Piled foundations are preferred to pad foundations and should be installed wherever possible.
  - ✓ The pile depth should be commensurate with the sites specific soil conditions
- Hybrid foundations e.g. piled and pad, are not recommended for cost saving purposes and should only be used where required due to local ground conditions or underground pipework, and only directly over the subterranean obstacle or impenetrable areas.
  - ✓ Be aware that different foundation types may result in differential settlement.
- Where engineered landfill is being used at the site, a subsidence report may be necessary to ensure suitability for siting the solar PV system and assess any settlement and/or impacts to groundwater levels.
  - ✓ Made up land should not be utilised for ground mounted solar PV projects.
- Dual-post piles are preferred over single-posts regardless of wind exposure due to wind damage experienced across the industry, including in low-exposure areas.

Supporting Structure

The supporting framework provides essential stability and resilience to the system and relies primarily on the appropriate installation of the foundation system.

- The main supporting framework should be of galvanised steel, avoiding the use of mixed materials.
  - ✓ Whilst aluminium offers several advantages, namely regarding cost and ease of fabrication, it may not perform as well as steel in areas subject to high wind or heavy snow loads.
  - ✓ The use of dissimilar metals such as combining galvanised steel and aluminium will result in accelerated corrosion and as such should be avoided.
  - ✓ Some dissimilar contact cannot be avoided, for example contact between module aluminium frames and the steel mounting frame. The use of insulating pads is recommended to reduce potential-induced degradation and galvanic corrosion.
- A structural engineers report must be commissioned to assess the suitability of the system for the planned location and geological features.
  - ✓ Ensure that recommended actions are adhered to as far as is practicable.
- Ensure the design specification and accompanying reports, such as Geotech, Flood, Ecology and Wind-load etc., are provided to your Solar PV Insurer and Broker, preferably at conceptual design stage. This can support positive and proactive engagement between developer and insurers.
- Careful consideration should be given to the use of solar trackers, which optimise the positioning of the panels/modules for greater energy yield. Whilst most have protective safety features, these must be suited to the local environment and require increased maintenance due to the reliance on moving parts. If elements of the tracking system are out of service or too slow to respond to weather events, the array becomes particularly vulnerable to wind and hail events.

  Note: Tracking systems may not be sufficient to safeguard Solar PV systems in locations vulnerable to severe weather events such as windstorm, hailstorms etc. Global industry loss experience so far does not indicate they perform any better from a risk perspective than fixed-racking systems.

Electrical Risks

- Electrical engineers should be qualified to install and maintain electrical systems in compliance with national regulations, standards, or codes. In the United Kingdom this is **BS 7671: 2018 Requirements for Electrical Installations IET Wiring Regulations (18th Edition)**.
  - ✓ Specific solar PV training courses are available to qualified electrical engineers, and any electrical engineer installing a solar PV system should have undergone such training and be able to provide certification upon request.
- Ensure the system design features appropriate lightning protection/earthing systems.
- Moisture and water ingress can cause electrical faults which can damage components and/or lead to fires. In addition, due to unpredictable climate patterns and the increase and intensity in sudden downpour/inundation rain events, where a significant amount of rain falls in a short period of time, all panels/modules and junction boxes should ideally be Ingress Protection (IP) 68 rated.
  - ✓ The lowest acceptable combiner box rating is IP54.
- The system components should be manufactured in accordance with national or international regulations and standards, such as:
  - ✓ **IEC 61215 - Terrestrial photovoltaic (PV) modules - Design qualification and type approval - Part 1: Test requirements**.
  - ✓ **IEC 61730 - Photovoltaic (PV) module safety qualification - Part 1: Requirements for construction**.
  - ✓ **IEC 62108 - Concentrator photovoltaic (CPV) modules and assemblies - Design qualification and type approval**.

- The system should be installed in accordance with national or international regulations, standards, or codes, such as:
  - ✓ **The Institution of Engineering and Technology (IET) Code of Practice for Grid-connected Solar Photovoltaic Systems**.
  - ✓ **NFPA 70 – National Electrical Code**.
  - ✓ **NFA 850 - Recommended Practice for Fire Protection for Electric Generating Plants and High Voltage Direct Current Converter Stations**.

Inverters

Inverters require adequate space to ensure air movement for ventilation and humidity.

- The installation should follow the Original Equipment Manufacturers (OEM) installation guidelines both for air flow rates, and vertical and horizontal clearance.
- String inverters should be adequately IP rated for external use and protected from direct sunlight as far as achievable.
  - ✓ An IP rating of at least IP65 is recommended in most jurisdictions, however this may need to be upgraded to IP66 or IP67 in areas with extreme dust or rainfall.
- **UL1741 Safety of Inverters, Converters, Controllers, and Interconnection System Equipment for Use with Distributed Energy Resources** sets out the manufacturing (including software) and product testing requirements for inverters used for grid connection applications.

Means of Isolation

- Ensure adequate isolators are installed on the system to allow immediate isolation in emergency situations.
  - ✓ These should typically be located on the inverters, combiner boxes, transformers and the main substation.

Panels/Modules

PV panel/module quality and reliability can vary depending on the manufacturing and design standards.

- It is important to ensure the manufactured panels/modules and installation are certificated to a recognised standard such as a minimum IEC 61215 and IEC 61730.
  - ✓ Ideally with an enhanced rating of Protection Class II, Fire Rating C.
  - ✓ Internationally, local equivalent standards should be used.
- The panels/modules need to be sufficiently resilient for the location and environmental factors such as anticipated wind speeds, snowfall etc.
  - ✓ The minimum standard for structural loading is 2400Pa of negative/upwards load (wind load), and 5400Pa of positive/downward load (snow load).
  - ✓ The risks of hail damage also need to be carefully considered and not installed in areas prone to significant hail events. To help reduce the potential for hail damage, panels/modules should feature tempered glass. Thicknesses vary from 1.6 to 3.2mm with a strong correlation between glass thickness and impact protection.
    - Modules with glass thicknesses below 2mm are not recommended.

Note: Bifacial panels/modules have glass no thicker than 2mm to shed weight and reduce overheating, which makes them slightly weaker in resistance to impact damage. They are also more prone to flexing and becoming loose during high wind conditions. Due to these issues, they are less suited to areas prone to wind or hail.

Cabling

Modules are strung together using string cables connected to each other via connectors such as MC4s. These transfer power from the strings to either string inverters or DC combiner boxes depending on the site set-up.

- Ensure cabling is installed to a good standard:
  - ✓ The string cables should be of sufficient length to allow for minor slack, preventing thermal expansion and contraction stresses, as well as for minor repairs without having to replace the entire string length.
  - ✓ They should also be restrained to the system, typically using cable ties.
    - String cabling should be located beneath the panel arrays, out of direct sunlight and in protective sleeves when bridging gaps between mounting frames.
    - They should not be overlong, or hang freely, as this risks getting them caught or touching the ground, which will result in accelerated deterioration and earth leakage.
    - Ensure sufficient cable ties are held at the site to effect any on site repairs.
    - Connectors such as MC4s should be fitted using purpose-built crimping tools, not pliers. Pliers apply uneven deformation, leading to weak connections and higher electrical resistance.
- The cabling from the combiner boxes should be located underground in backfilled cable ducting to help avoid wear and tear, trapping and breakage, impact, or weather related damage etc.
- The cable duct openings should be located sufficiently above the known maximum surface water levels and 'stopped' to prevent water ingress.
  - ✓ In any areas where underground cabling is not achievable, appropriate cable trunking/trays should be utilised and located in areas where the risks of damage are minimised and suitably protected.

Customer Substation Buildings

These standalone structures are critical to the safe management and distribution of electricity from the site to the power grid, as well as often housing monitoring and control equipment.

- Ensure switchgear buildings are of non-combustible construction.
- Switchgear buildings should feature good quality climate controls to remove any moisture and control humidity.
  - ✓ Aviva have seen premature and severe failure of switchgear due to wear and tear accelerated by insufficient climate controls.
- Cable pits beneath switchgear buildings should be maintained clear of water, which not only degrades the insulation but also contributes to increased humidity within the enclosure, accelerating equipment deterioration and increasing the potential for major faults.
  - ✓ Sealing cable entry points is recommended.
  - ✓ Installing an automatically operating sump pump can also help clear water accumulations promptly.
- Early detection of fire in switchgear units is essential.
  - ✓ Ensure automatic fire detection equipment is planned for switchgear buildings.
    - In the United Kingdom such systems should preferably be compliant with **BS 5839-1:2017 - Fire detection and fire alarm systems for buildings - Code of practice for design, installation, commissioning, and maintenance of systems in non-domestic premises,** and be installed by an accredited installer e.g. approved to BAFE scheme **SP203-1 Fire Detection and Fire Alarm Systems** or Loss Prevention Certification Board Loss Prevention Standard **LPS 1014 – Requirements for Certificated Fire Detection and Alarm Systems Firms**.
    - These systems should be monitored via an accredited Alarm Receiving Centre (ARC) to help ensure any incidents are reported promptly to responsible appointed persons.
  - ✓ Ensure detection systems are interlocked to power supplies to isolate power automatically upon activation.
    - This will isolate electrical systems and potentially prevent fire development.
  - ✓ Installing a monitorable video surveillance system (VSS) within the switchgear building allows designated persons to view the area remotely for arising hazards and issues, without unnecessary travel to the site.

- Do not plan to install office equipment, document storage etc., in the same room as switchgear cabinets. As live high voltage areas, these environments must be maintained as sterile environments.
    - ✓ Access should also be limited to designated persons only, as sanctioned by the Senior Authorised Person.
- Installing an automatic fire suppression system within the switchgear building can help reduce the potential for fire damage. These systems operate by detecting combustion products and releasing a suppression agent which suppresses or extinguishes the fire.
    - ✓ Such systems should be designed by an experienced and competent company.
    - ✓ Ensure any automatic suppression systems are interlocked to power supplies to isolate all power automatically upon activation.
        - ▪ This will help prevent reignition once the suppression agents have been exhausted.
    - ✓ Activation of active fire suppression systems should result in an alarm alerting the site teams.

Note: Any plans to install fire protection systems should be discussed with your Insurer and Broker, who can provide guidance and advice.

Transformers

The site will require a number of Medium Voltage (MV) transformers, and in some cases export transformers. An auxiliary transformer will often also be present to take power from the grid to power ancillary equipment at the site e.g. lighting, fire protections etc.

Note: All transformers should be manufactured, tested and installed to recognised national or international regulations, standard or codes. In the United Kingdom this is addressed in **BS EN IEC 60076 - Power Transformers**.

- Transformer maintenance including oil and gas sampling should be carried out as recommended by the manufacturer, with general HV maintenance taking place at least once annually.
- Synthetic cooling oil is preferred over mineral oil (KNAN over ONAN) due its higher ignition point, helping to reduce the potential for ignition.
- Cable pits are to be kept as clear of water as possible, either by applying sealant or installing sump pumps. Water accelerates degradation of the insulation, can cause faults, and increases moisture in the enclosure, accelerating corrosion.
- Cable terminations should be checked annually and should protrude perpendicular to the transformer surface. Minimum bending radii must also be adhered to. Metal support struts should be used if necessary to reduce sagging which may accelerate failure of the termination at the bushing interface.
- Clearance distances should comply with **BS EN IEC 61936-1 Power installations exceeding 1 kV AC and 1,5 kV DC - AC**, which are proportional to the transformer construction, oil type and volume.

System Controller and Monitoring

The system controller oversees the entire solar PV installation, controlling and protecting the key components and communicating performance data to the monitoring system. The monitoring system is responsible for communicating data to key users/managers etc.

- The solar PV system should be monitored and configured to alert key personnel in the event of any reported performance discrepancies or deviations.
- Ensure adequate communications redundancy.
    - ✓ Dual transmission systems should be considered where provided or available.

Having the appropriate monitoring with an aligned cause and effects logic, to safely shut down or isolate the array or sections of the array, coupled with a commensurate response will hopefully prevent any event escalating to a fire.

Testing and Commissioning

The solar PV system including mechanical and electrical connections should be thoroughly inspected prior to commissioning to ensure compliance with design specifications and installation standards.

- Electrical Testing will need to be completed including insulation resistance testing, continuity testing, earth resistance testing.
- Performance Testing should be completed to verify the system's performance under actual operating conditions. And comparing to the design specifications.
- Prior to connecting to the system to the national power grid, some form of approval testing may be necessary. In the United Kingdom this is addressed in **ENA Engineering Recommendation G99** and will need to be completed in conjunction with the relevant Distribution Network Operator (DNO) to ensure the system connects safely to the national grid.
- A commissioning report will be provided to confirm compliance with design specifications.

Emergency Response

An emergency response plan should be produced specifically developed to outline key responsibilities and actions in an emergency event including breakdowns. The emergency response plan should include best practice responses to all likely property and business interruption risks including fire, malicious damage and weather related exposures e.g. flood, storm etc.

The emergency response rules should be formally documented, and appropriate training provided.

Fire and Rescue Service

- Check whether there are any defined national or local requirements to notify the Fire and Rescue Service of the planned ground mounted solar PV installation.
  - ✓ Whilst not always a requirement, such disclosure can aid the Fire and Rescue Service with deployment of firefighting resources and allow for any pre-emptive planning in respect of run off containment to be undertaken. Accordingly, you should invite the local Fire and Rescue Service to inspect the site, and surrounding area, to evaluate fire risk exposures, determine water supplies, access and egress routes etc.

To support firefighting, the water supplies available for Fire and Rescue Service use should be understood. Site management should therefore establish:

- What fire water is available – hydrants, boreholes, tanks, canals etc.
- Whether site access is possible and whether new road infrastructure is necessary.
- Whether additional access platforms or hard standing surfaces are required for fire and Rescue Service vehicles.
- If hydrants are present - static pressure flows and residual pressure test results.
- Where hydrants are present these should be documented in an emergency response plan or shown on appropriate drawings.

Aviva Loss Prevention Standard **Manual Fire Fighting Water Supplies** provides further guidance.

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Sources and Useful Links

- BS 5839-1:2017 - Fire detection and fire alarm systems for buildings - Code of practice for design, installation, commissioning, and maintenance of systems in non-domestic premises
- BS EN IEC 61936-1 Power installations exceeding 1 kV AC and 1,5 kV DC - AC
- BS EN IEC 60076 - Power Transformers
- BAFE SP203-1 Design, Installation, Commissioning and Maintenance of Fire Detection and Fire Alarm Systems Scheme
- LPS 1014 Requirements for certificated fire detection and alarm systems firms
- BS 7671: Requirements for Electrical Installations. IET Wiring Regulations

Additional Information

Relevant Aviva Loss Prevention Standards include:

- **Grid Scale Battery Energy Storage Systems**
- **Ground Mounted Photovoltaic Solar Farms Security**
- **Ground Mounted Photovoltaic Solar Farms – Security Checklist**
- **Temporary Works - Introduction**
- **Flood Guidance and Mitigation (Global)**
- **Flood Guidance and Mitigation (UK)**
- **Business Continuity**

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