Loss Prevention Standards – Asset Classes

Roof Mounted Photovoltaic Solar Panel Systems - General Considerations

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Roof mounted solar arrays are present on many buildings and becoming more common. From planning to have them through to their end of life, these power generating devices present many additional hazards and exposures to a property.

This document is one of a series, to provide guidance to identify and mitigate the risks associated with these arrays.

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Roof Mounted Photovoltaic Solar Panel Systems – General Considerations

Introduction

Whilst roof mounted solar panel installations may support and align to an organisation's sustainability objectives with benefits to the environment, the economy, and power generation, they also present additional hazards to life safety and to a building: electric shock; additional static and dynamic loading; wind uplift; routes for water ingress; increased fire load; ignition sources etc., and based on their location, the obvious associated challenges with appropriate fire detection, safe emergency response and fire extinguishment. While solar panels on a roof do have many benefits, they should be considered as an additional hazard or exposure, to the property they are installed upon.

The provision of such an arrangement should not be considered in isolation. In addition to the cost benefit to install and utilise an array, the existing and exposed property values and business activity must also be considered. As such, the exposure of an array on one roof is not the same as the array on another.

The standards in this series discuss the 'property' risk management measures to support the installation and use of roof mounted photovoltaic (PV) solar panel systems, through to their end of life and safe decommissioning, with the aim to make the array truly sustainable and avoid any incidents or losses. These documents do not discuss life safety aspects in any detail nor grid scale ground mounted arrays.

If there are any plans to install a new array, decommission, or isolate an existing array or if a building planned to be occupied has existing arrays, then please contact your Insurer and Insurance Broker as early as possible to discuss Risk Management advice.

Internet Search

An interesting article from June 2023 in the PV Magazine*, highlighted that Clean Energy Associates (CEA) performed safety audit on more than 600 rooftop PV systems across many countries and found that 97% of installations had major safety concerns. This focussed on the PV modules themselves…

- 49% have grounding issues – caused by:
  - Incorrect installation.
  - Incorrect cleaning methods.
  - Walking on modules.
  - Extreme weather events - hail or wind.
- 47% have damaged modules.
- 41% have cross-mated connectors.
- 40% have poor terminations and improperly assembled connectors.
- 31% have module hotspots.
- 27% have cables on sharp edges.
- 26% have broken or damaged connectors as well as water ingress.
- 19% have enclosure hotpots.

*CEA and major safety concerns – PV Magazine International

However, cabling and inverters are the highest sources of fires ahead of the 'module' caused fires. Please review the TUV paper from 2017 on Technical Risks in PV Projects.

In addition to the above, while the risk of solar panel fires is low, based on their location and the difficulty in safely extinguishing such a fire, to get an understanding of the nature and impact of fire, please complete an internet search of 'roof solar panel fires' and look at some of the results. The impact can be devastating.

Background

PV solar panels can vary in size and weight, and come with various types of fixings, and associated equipment such as electrical cables, connectors, junction boxes, isolation switches, inverters, etc. PV solar panel systems are often seen fixed onto roofs or purposely built into the roofs of residential homes, and industrial and commercial buildings.

PV solar panel systems operate by collecting solar radiated energy and converting it into electrical power. The solar panels contain large numbers of PV cells made of semiconductor materials that convert the energy into direct current (DC). The DC runs through electrical cables, connectors, and junction boxes via a DC isolation switch and then to a power inverter. This inverter converts the DC into alternating current (AC) that runs via an AC isolator to the main electrical supply switchgear. In some cases, the DC power can be stored in batteries 'offline' and used as a standby supply (Battery Energy Storage Systems (BESS)). The latter is not discussed in this standard.

Array Schematic

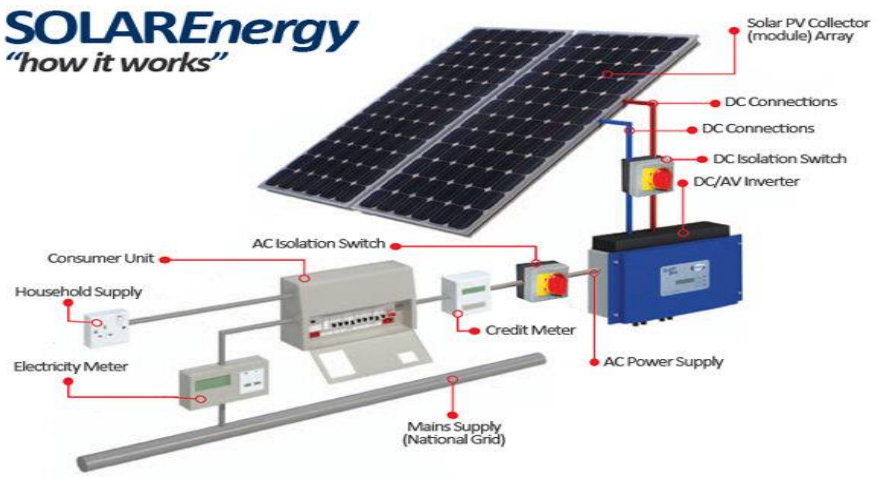

Figure 1 - Basic photovoltaic system

Bifacial Solar Panels

Bifacial solar panels have photovoltaic cells on both sides of the panel. This increases the efficiency of the panel as it receives light that is reflected onto the back to the panel and generates DC from both sides.

If bifacial panels are being considered or are installed, specific attention is needed to ensure they are cared for on both sides of the panel. Consider the damage to the underside of the panel; the fixings; the ongoing inspections, maintenance, and servicing… through to making them safe at their end of life.

Note: Bifacial panels should never be installed flush against a surface. They are designed to capture diffuse and reflected light underneath. Any claims made that they have a better fire resistance than mono facial panels, remains to be confirmed. In Aviva's view, bifacial panels being installed flush or close against any surface is not something they are designed for, and the drawbacks are substantially worse than the likelihood of improved fire resistance.

Vertical Bifacial Installations

Bifacial panels installed vertically with the correct orientation towards the rising and setting sun, have many advantages:

- They can see morning and afternoon sun when the sun is rising and setting.
    - Power generation is achieved at peak times of the day for power consumption.
    - Because they generate electricity at peak times, they also spread the load of generation. i.e., it is not generated in the time of the day when other 'standard' arrays are generating. At peak times the benefit per kW generated is greater.
- As the panels are installed vertically, there should normally be less exposure to damage from objects from above, such as:
    - Hail
    - Stone strike dropped from birds. See 'Potential Causes of Fire' section later in this document.
- Because the surface facing the ground is the narrow side of the panel there is less accumulation or waste and detritus below.
    - They are also less attractive to pests such as rodents and birds.

However, mounted upon a roof, there is one significant additional exposure for these panels and their fixings. The vertical face is the largest surface area and so the potential to be damaged or physically lifted by the wind is a greater challenge than for standard arrays. This additional wind uplift must be included within any design calculations.

Microgeneration Certification Scheme (MCS)

A number of countries have developed their own national standards and/or guidance documents including, in some cases, product certification schemes. These standards and documents are often completed in conjunction with the PV solar panel industry, covering manufacturing, design standards, installation, servicing, and maintenance, etc.

In the UK the Microgeneration Certification Scheme (MCS) is a nationally recognised quality assurance scheme which covers products and installation of microgeneration technologies, including PV. https://mcscertified.com/.

In the UK, the installer must be Microgeneration Certification Scheme (UK scheme) certified or equivalent (if there are less than 5 employees at the installing company). In other territories, a similar local equivalent should apply.

The MCS states:

- Working with industry, the MCS defines, maintains, and improves Standards for low-carbon energy technology products, contractors, and their installations. MCS is a mark of quality. Membership of MCS demonstrates adherence to these recognised industry standards, highlighting quality, competency, and compliance.

Aviva recommends that the requirements of the Original Equipment Manufacturers (OEM's) guidance and in the UK the:

- MCS criteria and
- Institute of Engineering and Technology (IET) Code of Practice for Grid-connected Solar Photovoltaic Systems,

are the minimum standards implemented and followed for design, installation, and ongoing maintenance and servicing. Internationally, local equivalent standards should apply.

The following standards support and enhance this guidance, based on the many variables that each arrangement exposes and from incident experience.

Note: The MCS applies to installations up to 50kWp (kilo watt peak power output), but the standards they support, remain largely applicable for installations greater than 50kW, as best practice.

Finally, based on the exact nature of the array on any roof, if the MCS or OEM guidance is not wholly appropriate to the installation, then the frequency of any tasks prescribed therein should be increased based on one's own exposure, arrangements, and knowledge. Also, even though the MCS is a mark of *minimum quality*, installations by MCS approved installers can still create and/or deliver substandard workmanship.

- The minimum requirements of the MCS and OEM should never be reduced.

Installation Conformity Certificate

With any solar array, an installation conformity certificate should always be obtained from the installer. This should identify that the array has been installed by a competent qualified person using equipment that complies with the relevant industrial, consumer and safety standards.

Risk Assessment, Method Statements and Management of Change

Throughout all stages of the process to install, care for and eventually decommission roof mounted solar arrays there should always be detailed formal Risk Assessments and Method Statements for each task. This should be supplemented by an understanding of any additional safe systems of work, such as Working at Height management controls and permits.

- Ensure the premises' Fire and Health and Safety risk assessments are reviewed and updated to take into account the PV solar panel system.
- A full Design Assessment is required to verify the provision of the solar array will not cause any adverse conditions in the operation of the site.
- Any existing licences or permits to operate the site should also be reviewed and revised accordingly, prior to any installation.

The provision of solar panels on a roof should be robustly managed by a Management of Change process. Please see Aviva's Loss Prevention Standard Managing Change - Loss Prevention Standards.

While these are asset-focussed Loss Prevention Standards, the fact the PV panels generate DC electricity, convert this to AC and the panels are live when they exposed to the sun increases the risk of electrical shock, injury, or death. This is especially relevant during a change, any testing or maintenance or in an emergency situation. As a result, in addition to the DC and AC isolators, there should be a rigorous set of risk assessments, method statements and enhanced control mechanisms such as a formal Lock Out Tag Out (LOTO) system, that protects anyone in the vicinity of the panels and the entire distribution network. Guidance for an appropriate Lock Out Tag Out programme can be found in many areas:

- Health and Safety at Work Act 1974 HSE HSWA
- Provision and Use of Work Equipment Regulations 1998 (PUWER) HSE PUWER
- The Electricity at Work Regulations 1989 HSE EaW
- BS 7671 – Requirements for Electrical Installations (18th Edition) The IET Wiring Regulations
    - Section 537.2.2.4 and Section 537.3.1.2 – gives additional guidance.

Working at Height

The simple fact that the solar array is located on a roof means any task associated with the provision, installation, ongoing care, and maintenance etc., will be at height. Please see Aviva's Working at Height LPS - Work at Height - Loss Prevention Standards.

It is not acceptable to install a solar array and then have *no provision for safe and regular access* for inspection, testing, and maintenance.

In relation to the roof, its access during construction and then ongoing, the following should be considered:

- Temporary and/or permanent safe access to the roof.
    - Scaffolding?
    - Access steps or ladders – external or internal to the building?
    - Cherry pickers, raised platforms or equivalent?
- Building edge protection – temporary and/or permanent.
    - Permanent edge protection is more beneficial from an ongoing inspection and maintenance standpoint, where regular access will be required.
- Roof skylights, vents, glazed elements etc.
    - Do these need protection with an appropriate metal grating cover (or similar) based on regional health and safety guidance, risk assessments and maximum expected loading, or protection for skylights?
    - Do these need the equivalent of edge protection.
- Is secure cabling, fixing arrangements, and harnessing needed to traverse the roof? etc.

Building Owner vs Tenants and Building Occupants

It is important throughout the process of having solar arrays installed or when the panels are already installed, to understand what is in place and who is responsible for them. Aviva understands that tenants within buildings may not be aware there are solar arrays on their roofs, what their status is and/or who is responsible for their ongoing inspection, testing, and maintenance. Likewise, some property owners are in a similar position. With an exposure such as this on a property, there should be no ambiguity in this provision.

A simple check could be to:

- Walk away from the building and look up or get a higher vantage point.
- Check tenancy agreements and contracts.
- Request roof access and physically inspect the roof.
- Use the internet and look at satellite imagery.
- Use a drone to conduct an aerial roof survey – see separate Loss Prevention Standard - Roof Mounted Photovoltaic Solar Panel Systems No. 4 - Installed and Ongoing Care for relevant section.

Impact of a Roof Fire

While there are many exposures in relation to the panels and their presence on a roof, fire is one of the most catastrophic with the largest potential impact. A fire starting in the array on the roof can spread to the roof structure and the building below… or a fire in the building or on the roof could impact the solar array on the roof.

The potential damage to a building from a roof level fire can be minor through to total involvement with, in the worst case, roof/building collapse. It can also spread to adjoining or exposed buildings or assets. It is worth noting that the impact of fire even if a roof/building is only partially damaged can be extensive. Depending on the materials of construction, the arrangements of the ventilation and ducting systems etc., smoke, acid gases and condensation damage can spread throughout many areas. In addition, any fire will need to be extinguished. A fire involving a solar array or on the roof will most probably cause damage to the fabric of the building/roof structure and will allow fire water and rain ingress. Aviva has seen significant and widespread water damage internally to buildings following a roof level fire (that started within the solar panels), even when the fire did not spread internally. This potential exposure must be considered when looking at the impact of an event involving the array installation.

- Potential fire spread – fires involving combustible roofs or combustible objects on non-combustible roofs will spread quickly, above any fire detection or fire protection that may be provided within the building.
    - Lack of fire suppression.
    - Increased wind speeds and availability of air to 'fan the fire'.
- Adjoining or nearby buildings can also be at risk.

Finally, during a fire or post any fire (regardless of the size) the additional weight presented by the solar array can cause:

- Structural integrity issues with the roof.
- Roof collapse when unexpected or quicker than expected.

As a result, when considering PV panel installation, one also needs to keep in mind that the provision of an array may affect a site's Loss Estimates for Property Insurance purposes. As a result, this may have implications to any insurance and reinsurance programmes.

Potential Causes of Fire

The cause of fires involving PV solar panels include but are not limited to:

- Poor panel and array installation; using incorrectly specified or incompatible equipment.
- Faulty or damaged equipment; PV panel edge seal damage.
- PV panel, joint and cable movement, fatigue failures, erosion, insulation degradation or damage (including personnel walking on the cables, cables on sharp edges).
- Microcracking of the silicon semiconductor layer below the external protective surface glass layer.
    - Microcracking is a form of damage that is invisible to the naked eye and can be most easily detected by thermographic imaging.
- Electrical system, inverter, and the DC isolators themselves e.g., DC arcing.
- Stone strike e.g., birds dropping stones (particularly from larger birds such as the crow or gull family) and impact damage from wind lifted debris.
    - Roofs with stone ballast can be more prone to this.
    - Larger damage can penetrate the glass layer, leading to moisture ingress (from rain), this can lead to corrosion and arcing. Aviva has seen fires start because of this.
- Wind damage and uplift.
    - Including the ballast (if used) that can damage the solar panels by their movement or impact.
- Moisture ingress and corrosion to all elements of the installation.

    - Junction box corrosion - directly related to its Ingress Protection (IP) rating. Incorrect IP rating of equipment accelerates moisture ingress and corrosion, which has been known to lead to short-circuits causing fires.
- Hail damage - impact.
- Lightning.
- Bird and vermin damage to cabling and panels – known to nest and live in the panel areas due to their warmth.
- Hot work and management of other traditional ignition sources such as smoking.
- Lack of appropriate ongoing inspection and maintenance.
- Poor isolation and decommissioning practices.

Smoking

Smoking and vaping must be prohibited from the roof at all times. This must only be permitted within a designated area at ground level. Please see Aviva's Loss Prevention Standard Smoking Loss Prevention Standards.

Hot Work

While this may not appear to be directly relatable to a solar PV installation, the careless use of 1 angle grinder to cut some cable trunking exposes the entire building for a fire. As a result, as part of any process to install, maintain, or repair a roof mounted solar array a formal hot work management system with associated permit should be utilised. Please see Aviva's Loss Prevention Standard Hot Work Loss Prevention Standards.

Emergency Services, Emergency Response and Business Continuity

If there is an emergency situation or fire associated with or exposing the solar panels on the roof, one needs to consider how that impacts the response and firefighting strategy of any site team and the Fire and Rescue Services.

- If everyone is out of the building and safe, and there is no life to save… what would their strategy be?

This is something building occupants and owners should understand from their local emergency services.

- Will the Fire and Rescue Services go up to roof level and try to extinguish the fire or will they fight the fire and protect the exposing assets from ground level?
- How will they access the roof? What provision is there?
    - Stairs or ladder?
    - Internal to the building or external?
    - Fire protected route or exposed?
    - Ladder truck?

Regardless of their approach, it will be based on their own risk assessment… and with no life to save, understandably the Fire and Rescue Services will not risk a life.

Questions to consider at site level:

- What resources do the local Fire and Rescue services have in relation to fighting a roof fire?
- What arrangements are there on site to aide this?
- Is this applicable for the height and layout of the building in question?
- Is this provision something that is known and formally documented?

What water supplies are available in the local area?

- Flow and pressure?
- Is this appropriate for the expected fire and height of the building?

If there is a fire within the building (not on the roof) and there are solar panels of the roof:

- How will this impact how they fight that fire? Will this impact their strategy?
    - With live DC?
- Of if they have to vent a fire from within a building and there are panels are on the roof – will this change their approach?

What about the fact a solar panel when directed towards the sun creates DC and is live. How will this DC exposure impact their approach? While not standard to a roof mounted array, a manual isolating 'fireman's switch' can be provided to support the DC isolation. This could be:

- Located in a safe area inside the building, accessible to the responders.
- On the outside of a building in a 'break glass' or 'safety box' arrangement

Or in some instances, the provision of a manual isolation switch for the AC supply, which is normally standard for most buildings, that is also interlocked to isolate the DC.

Note: Any 'fireman's switch' should be clearly labelled and distinguished between the solar array control panel and the emergency isolation for emergency responders itself.

Any PV panel power isolation switches:

- Need to be located in readily accessible and safe areas,
- Be clearly signed, and
- Labelled in appropriate drawings and provided to the Fire and Rescue Services in the sites Emergency Response Plans/Grab Bag,

to allow safe access by the on-site emergency response team, the maintenance team and the Fire and Rescue Services. In some instances, remotely operated controls to operate isolation switches away from the area of fire could also be considered.

Building Emergency Response Plans and Team

With the provision of roof mounted solar panels, the existing site/building emergency response plans and emergency response team need to be reviewed and revised. Who will:

- Respond to an alarm raised and emergency situation?
- Operate any PV panel isolation switches?
- Liaise with Fire and Rescue Services? etc.

How will this provision impact any evacuation plans and muster areas? All associated plans and drawings should be updated.

Business Continuity Plans

With a PV installation, the existing Business Recovery, Salvage and Continuity Plan(s) will need to be reviewed and revised where necessary. This may include the need to engage with specialist PV panel contractors to safely recover the building post incident and understand the financial impact if the array is not available to generate power.

Training

Anyone engaged with the installation, inspection, testing, maintenance, or emergency response of the solar arrays and the associated equipment, should be appropriately trained and skilled to complete such tasks and be aware of the safety management systems that support them e.g., hot work, working at height, lock out tag out etc.

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- Electrical inspections and thermographic imaging: Bureau Veritas
- Thermographic imaging and PAT testing: PASS
- Automatic fire detection and portable extinguishers: SECOM
- Security marking: Selectamark

For more information please visit:

Aviva Risk Management Solutions – Specialist Partners

Sources and Useful Links

- Guide to the Installation of Photovoltaic Systems: Published by the Microgeneration Certification Scheme (MCS) https://mcscertified.com/

Additional Information

Relevant Loss Prevention Standards include:

- Roof Mounted Photovoltaic Solar Panel Systems - General Considerations
- Roof Mounted Photovoltaic Solar Panel Systems - Installation and Construction
- Roof Mounted Photovoltaic Solar Panel Systems - Installed and Ongoing Care
- Roof Mounted Photovoltaic Solar Panel Systems - Isolated End of Life and Decommissioning
- 15 Top Tips for Roof Mounted Photovoltaic Solar Panel Systems
- Contamination Following a Fire
- Control and Management of Combustible Waste Materials
- Electrical Installations – Inspection and Testing
- Emergency Response Teams
- Third Party Property Exposures
- External Wall Insulation Systems
- Fire Compartmentation
- Fire Safety Inspections
- Heat and Smoke Venting Systems
- Housekeeping
- Managing Change - Property
- Managing Contractors
- Smoke Contamination
- Smoking and the Workplace
- Thermographic Surveys

To find out more, please visit Aviva Risk Management Solutions or speak to one of our advisors.

Email us at riskadvice@aviva.com or call 0345 366 6666.*

*The cost of calls to 03 prefixed numbers are charged at national call rates (charges may vary dependent on your network provider) and are usually included in inclusive minute plans from landlines and mobiles. For our joint protection telephone calls may be recorded and/or monitored.

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