Risk Control Guide

PHOTOVOLTAIC (SOLAR) PANELS

Introduction and Scope

The purpose of this document is to give guidance to end-users of photovoltaic (PV) plants for roof and ground-mounted installations.

Photovoltaic is the term used to describe the direct conversion of light energy (photons) into electrical energy by means of semiconductors. This enables the light energy received from the sun to be converted directly into a useful form of electrical power.

There are 2 recognised technologies:

- Crystalline Silicon PV Cells is the most common but requires a larger investment due to the high silicon content. Sub-types of this technology are (in decreasing order of efficiency): monocrystalline, polycrystalline and thick-film panels.
- Thin Film PV Cells is a newer development that requires only a fraction of the silicon content but does result in a lower electrical efficiency (around one half of crystalline ones).

The most common type is polycrystalline silicon.

The document is intended to give guidance on:

- Design and installation.
- Property risks.
- Operation.
- Maintenance and inspection.

The primary property risks are:

- Impact damage due to hailstorm, falling objects or malicious damage.
- Damage by extreme weather – wind, snowfall, lightning strike.
- Electrical failure and overheating leading to fire, caused by incorrect plant design, component corrosion, hot spots, damaged modules, loose/low quality connections, extreme hot weather, temperature cycling fatigue.
- Theft – especially copper cables.
- Fire resulting from electrical damage, arson or fire spread from the building/open field to the plant.

All items are relevant to both new and existing installations unless specified otherwise.

System Components and Specifications

Terminology

The main components of a PV plant are:

- PV cell: small electrical device (15cm x 15cm) that converts the energy of light into DC electricity
- PV array: linked collection of PV modules, usually wired by MC4 connectors. They are installed on structures that can be fixed or moving (solar trackers)
- Junction box: enclosure where modules and PV arrays are interconnected
- Inverter: power electronics equipment which converts the direct current (DC) output of a PV array into a utility frequency alternating current (AC)
- Transformer: passive equipment used to step up the AC voltage. They can be dry or oil-filled.
- UPS: uninterruptible power system including batteries mainly used to back up control systems.
- Wiring, grounding and metering equipment.

Standards

Ensure the system is designed and installed accordingly to internationally recognised standards and meets any relevant local standards.

Less combustible PV panels, such as those with glass, aluminium or lower combustibility backings, should be approved to UL760 Class A where installed.

Design and Installation Considerations

There are important factors to consider during the design and installation of the PV panel system, which affect both the system performance and the control of risks. A fire on the roof is difficult to control using manual firefighting. The PV panels are plastic make-up and some roofs are combustible. So, a fire spreading throughout the installation and involving the roof materials can be devastating.

The main considerations are:

Construction:

1. Do not install PV systems on expanded polystyrene sandwich panel roofs.

2. Other combustible roofs (unapproved sandwich panels or felted steel/concrete deck roofs with no full-scale fire test certification) or roofs with combustible coverings should have the following installed where roofing materials cannot be removed:

    - Apply a fire-resistant roof covering (these should be reviewed by RSA on a case-by-case basis) as:
        - Gypsum or calcium silicate barriers (this is ideal and should be used for combustible roofs with combustible insulation).
        - Fire protection blankets (these can be used for combustible roof membranes).

    OR

    - Class 0/Class A PV panels throughout.
    - Strictly apply a spacing between banks of PV panels of 1.2m every 45m in each direction.

Layout:

3. Do not install PV panels over or within 1.2m of skylights. Any skylights to be covered by PV installations should be covered with a fire resistive or non-combustible cover as agreed with RSA.

4. Do not install PV panels over roof or ground drains.

5. Provide a spacing of 1.2m every 45m in each direction and short of the roof edges for fire brigade access, access for gutter clearing and for inspection of roof drains & bolt fastenings.

6. Provide access and walkways to guttering and roof drainage to ensure inspections and debris clearance can be carried out.

7. Ensure smoke vents can open fully with the PV panels in place.

8. Provide 150mm clearance between the panels and the roof for ventilation and to reduce potential fire radiant heat feedback.

Cabling:

9. Limit the length of DC cabling as much as possible.

10. Provide earth cables to protect all metallic structures, components and cable trays. The earth cables should be at least 6mm^2 cross section. Lightning protection down-conductors must be at least 35mm^2.

11. Use cables that are UV and water resistant, or otherwise protected from direct sunlight to avoid UV damage. The preferred cable type XLPE insulation, LSZH outer sheath, and steel armour.

12. Place all cables on mesh or perforated cable trays to avoid contact with any combustible roof membrane and to allow for adequate ventilation. If provided, tray covers must be at least 100mm from the tray top, otherwise they should be removed to allow heat dissipation. Install no more than 2-no cable levels in each cable tray. When pipes are used, check their deterioration and ensure they are filled within limits consistent with International or recognised local electrical Codes.

13. Use MC type, IP-68 (or recognised local International equivalent), UV resistant DC connectors, avoid pierced connectors.

14. Avoid contact with sharp points (i.e. rough concrete or metal edges).

15. Route cabling through steel conduit through roofs and walls to protect against mechanical damage and to protect combustible constriction materials against electrical incidents.

Electrical Installations:

16. Inverters should be freestanding on a metal frame or mounted against a fire-resistive wall, and always more than 2m away from any combustible construction materials. Alternatively, they should be contained within a non-combustible, fully enclosed room (1 hour fire rated), fitted with automatic smoke detection (and/or sprinkler protection where provided elsewhere).

    Inverters should be accessible for maintenance and not located on the roof.

17. Transformers should be physically or spatially separated from the surrounds due to their inherent fire risk. A 2 hour fire-rated room or 10m separation distance is recommended.

18. Remote DC isolators should be installed on the DC side of the inverter to allow manual isolation and safe manual firefighting. Or the main building fire brigade isolator should shut down the PV installation so that manual firefighting is deemed safe. Consult the local fire brigade for advice.

19. Install by-pass diodes (optimiser) to isolate PV panels on fault and to continue operation of PV panels in series with it. This prevents hot spots whilst maintaining efficiency of the installation.

20. Use only one type of electrical connector throughout the installation as mixing connectors is know to cause electrical arcing.

Fire Protection:

21. Install dry risers for manual firefighting on the roof. Space and arrange in line with a recognised standard.

Natural Hazards

Ensure the system is designed to withstand the local environmental conditions including:

- Nominal and maximum wind speeds
- Hailstorm
- Dust-storm
- Earthquake
- Lightning
- Snow loading

Wind loading:

- Use recognised International or local codes for the wind design of the fixings.
- Note that it is likely that equipment located around the roof perimeter may require additional fixings.
- If wind resistance cannot be ensured, wind deflectors that prevent wind from penetrating underneath the panel array should be evaluated and installed to provide sufficient wind resistance.
- Typical wind resistance for modules may be 2,400Pa (uplift); however this will increase depending on the wind exposure present.

Roof loading:

- Ensure the extra loads from the system on the roof do not affect the roof load design and safety factors are not compromised.
- Ensure any additional loads caused by snow loading, snow drifting, ice and sand do not affect the roof load design and safety factors are not compromised.

Panel mounting:

- Mount the panel support racks mechanically to the roof structure, avoiding adhesive and ballasts as they are known to be unreliable during heavy winds.
- Fix to the main roof structure provided this does not breach the insulation/ waterproofing membrane, otherwise use clips which are approved by the roof manufacturer or appoint a structural engineer to complete calculations to provide fixing adequacy.
- Provide double nutting for the panel bolts where periodic re-tightening is not possible, use a stainless-steel lock nut with a nylon insert for the second nut.

Lightning:

- Provide lightning protection (air-termination rods and conductors) for any roof-mounted PV plant if required by assessment recognised International of local codes (eg. IEC 62035 risk assessment tool).
- Separate PV systems by at least 1m from lightning protection. When this is not possible (i.e. insufficient distance or metal roofs), special high-voltage insulated lightning down conductors (e.g. HVI conductors) should be used to avoid dangerous sparking. Otherwise, they should be included in the equipotential bonding using suitable lightning current and surge arrestors at the entry to the building. All metallic components without a conductive connection into the building must be connected directly to the lightning protection.
- Provide inverters, junction boxes, communication lines, connections to the electrical grid and equipotential bondings between grounding systems with lightning (surge) protection devices.

Operational Considerations

- Ensure panel covers remain in place until the arrays are fully connected.
- Ensure remote load monitoring and alarm management is provided, including the panels and inverters. The alarms should signal to a permanently manned station or to a cascade of site personnel contact numbers who can remotely check the plant condition.

Crime

Theft of solar panels and electrical cable is relatively common, and the risk is further increased during installation. Provide the following:

- Provide perimeter fencing to ground installed PV systems to prevent access to yard areas and PV compounds.
- Ensure points of entry to the roof are controlled and monitored. Internal roof access doors should be normally locked and external access points such as ladders should have access restricted using ladder guards that are locked in position.
- Provide remotely monitored closed circuit television (CCTV) at access points as a minimum.
    - Unless 24-hrs/day and 7-days per week security guarding is provided, the CCTV should include detection of human intrusion, such as via video analysis and a clear response plan defined detailing actions to be taken after an activation.
- Provide ‘tighten and break’ anti-theft screws to fasten panels to mounting frames for new installations unless 24-hrs/day and 7-days per week security guarding is provided.
- Provide forensic marking of cables for new installations unless 24-hrs/day and 7-days per week security guarding is provided.

Emergency Planning

Ensure the Emergency Response Plan includes:

- Details of the location of the main electrical components, isolation points and roof access locations.
- A list of people that can attend rapidly in the event of a fire to assist the fire brigade in ensuring that the installations are disconnected.

Complete pre-planning with the local public fire service. This must ensure that adequate access, water supply and electrical shut-offs are available to allow fire-fighting and that the fire service are familiar with these features.

Protection and Detection

Assess the financial impact of a fire in important areas. Review the need for the installation of automatic gaseous fire suppression for areas such as electrical rooms and cabinets, for example rooms housing inverters and switchgear. Install where the cost of fire protection is cost effective in agreement with RSA.

Provide automatic fire detection linked to a constantly attended location in electrical rooms and cabinets, including rooms or cabinets containing inverters, transformers, batteries, power factor correction equipment and switchboards.

Install arc flash detection integrated in the inverter.

Maintenance and Inspections

Implement documented maintenance procedures covering all aspects of the system including the panels, support structures, trackers, electronics, electrical cables and components.

Complete based on local conditions:

- Regular cleaning (e.g. dust, bird dropping, etc.). The cleaning intervals should be modified based on the results of weekly inspections. The panels should be cleaned with clean water to remove surface dirt and salt. It is essential to clean panels regularly as partial shading can lead to hot-spots that cause the panel to deteriorate leading to faults that cause fires.

Complete weekly:

- Visual inspections including; panels, electrical/grounding cables and connections, junctions boxes, diodes, switchgears, DC conditioners, transformers, UPS, DC/AC invertors and auxiliary components such as fuses and switches for signs of deterioration, dirt or overheating. Any damage must be addressed promptly.

Complete 3-monthly and before heavy wind or rain storm:

- Inspections for debris, deterioration and peeling and removal of any loose objects, leaves, etc. Check that gutters and drains are clear of debris. Check that safety barriers are in good condition and firmly fixed in place.
- Remove vegetation from around ground installations to reduce the fire load in dry weather conditions.

Complete (at least) annually:

- Formal inspection of the condition of all electrical/grounding cables and connections, junction boxes, diodes, switchgears, DC conditioners, transformers, UPS, DC/AC inverters, plus auxiliary components such as fuses and switches.
- Checking of the electrical and control connections for tightness, deterioration and corrosion.
- Infrared thermographic surveys (at least twice per year where combustible roof materials are present) including all electrical equipment such as inverters, wire connectors, junction boxes, switchboards, transformers, modules, etc. The inspections must be done at a time when there is a significant panel loading (i.e. clear weather and peak generation times).
- Check the panel structure including condition of the support structure and tightness of fasteners.
- Oil analysis on any oil-insulated transformers including dissolved gas in oil (DGA) analysis.
- Replacement of air filters on invertors if in dusty environments.
- Check the operation of by-pass diodes by injecting current outside daylight hours and check the diodes become active.