PHOTOVOLTAIC PANEL

Introduction

The purpose of this document is to give guidance to end-users of small scale PV plants, including roof-mounted installations and those mounted at ground level.

Photovoltaic is the term used to describe the conversion of light energy into electrical energy. PV power plants eliminate the need for a machine driven generator by harnessing the light energy received from the sun and converting it 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. 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.

The following factors are considered within the scope of the document:

- System components and specifications.
- Installation considerations
- Operational considerations
- Inspections and maintenance
- Property risks
- Loss expectancies

System Components and Specifications

The PV generating system should be designed according to internationally recognised standards. The International Electrotechnical Commission (IEC) standards that apply are:

IEC (EN) 61215 Crystalline Silicon panels
IEC (EN) 61646 Thin Film panels
IEC (EN) 61277 PV generating systems general guide
IEC (EN) 61721 PV module impact resistance

The Underwriters Laboratory standard for PV panels UL 1703 also applies. Other local standards may be applied by location, such as VDEW in Germany and ADEME in France.

Installations should be designed for a life cycle of at least 20 years, but bearing in mind that the performance will drop off by approximately 10% every 10 years.

Installation Considerations

There are important factors to consider during the installation of the PV panel system, which affect both the system performance and the control of risks. The main considerations are:

Project outline

- Component weight – roof strength or soil conditions
- Local environmental conditions, including nominal and maximum wind speeds, hailstorm and dust-storm risks, earthquake and flood zoning.

- Taking into account the dust and water ingress potential of external equipment, components should be IP-65 rated (Europe) NEMA 4 (North America), meaning they will not allow dust ingress and are resistant to normal strength water jets.
- Contract conditions between various parties, for example the system owner, the electrical company and the owner of the building or land.
- Maintenance contracts should be formalised, covering all aspects of the system including the panels, support structures, electrical cables and components.

System Layout

- Natural ventilation is required below the panels to allow for correct cooling and therefore to reduce potential downtime if the junction box disconnects automatically at high temperatures. The panel modules should stop at least 1m short of the roof edges, to allow direct access to the roof by the fire brigade. Keep at least 50cm clearance between modules and any other metal structures such as lightning rods and smoke vent frames, to avoid arcing. Ensure smoke vents can open fully with the panels in place.

- The electrical cabling system should be designed and installed to avoid physical rings that would represent a risk of heating by induction. The cables should be protected from direct sunlight to avoid UV damage. They should be placed on perforated cable trays to avoid contact with any combustible roof membrane and to allow for adequate ventilation so that over-heating does not occur. This is particularly relevant in hot regions. Earth cables should be in place to protect all metallic structures, components and cable trays. The earth cables should be at least $16mm^2$ cross section. Lightning protection on roofs should be directly connected at roof level to the earth cables of roof-mounted PV panel systems. Metal roofing and steel frame bonding cables should also be connected directly.

- Where DC/AC inverters also have a transformer installed to raise the voltage for export to the public grid, the transformers should be physically or spatially separated due to their inherent fire risk. Inverters should be freestanding on a metal frame or mounted against a fire-resistive wall. Manual decoupling of the panel modules from the DC installation should be done by a dedicated device. This is required in addition to the DC cut-off in the junction box and the AC cut-off during installation and maintenance. Modern inverters have a circuit breaker integrated in the box, to enable remote control. The modules should have sturdy DC connectors for easy and assured coupling, thus improving safety of contractors and avoiding loose cabling.

Operational Considerations

- The modules are linked in series, typically 15 – 20, to provide adequate power at the inverter. The linked modules are called an array. Avoid having the PV panel modules connected in series whilst not connected to the grid. The electrical current generated in a module array could result in an arc to any earthed construction. The individual panels are normally supplied with an opaque material cover in place to avoid electricity being generated. These covers should remain in place until the arrays are fully connected.

- The inverter needs to be managed for the event of a grid disconnection, either due to a line fault occurring or for planned maintenance of the utility line. In the event of an outage on the grid, the continued feed of electricity from the PV installation would create a local power island, which could be dangerous for utility workers who expect the area to be unpowered. Inverters therefore include ‘islanding’ detection. The result can be intentional islanding, where the grid connection isolates and the electricity is looped back to provide back-up power to the local site. If intentional islanding is not required then the inverter simply disconnects and the PV installation stops supplying any power. When the power outage ends, the islanding detection allows the inverter to automatically re-connect to the grid.

- Ensure that adequate security measures are in place, taking into consideration the frequency with which the site is visited and the values at risk. Access to the site or roof must be restricted. For roof mounted systems consideration should be given to the possibility of using nearby storage/structures/waste bins etc, to gain access to the roof. For ground level systems that are not visited daily more active security systems should be considered, including detector-activated CCTV cameras (on site or remotely monitored), good levels of lighting, perimeter fence vibration alarms, perimeter IR-beam alarms etc. However, for remote sites even active security measures can be ineffective if the response time by the police or alarm company is significant. Therefore passive measures that slow down potential thieves become important. The PV panels themselves should not need to be removed regularly for maintenance and therefore consideration can be given to using screw-fixings that are difficult (time-consuming) to remove. Copper cables are very attractive to thieves and therefore the more substantial cables, such as those passing from the arrays to the inverters, should be fixed by some means, for example by pouring concrete into the underground cable run. Cables that are only fixed at each end can easily be removed once cut.

- Commercial PV installations should be provided with remote load monitoring and alarm management, to include the panels and the inverters. The alarms should signal to a permanently manned station or to a cascade of contact phone numbers of site staff where staff members have the option to remotely check the plant condition. Alarm levels should be determined through actual site measurements and thereafter should be regularly reviewed and modified as required. The site emergency plan should include the actions to be taken in the case of a significant load change, for example due to a short circuit, when site intervention would normally be required. The emergency plan developed for the plant should be incorporated into the building emergency plan in the case of roof-mounted systems. The location of the main electrical components and the DC isolation point should be shown, plus the roof access locations.

Maintenance and Inspections

- All maintenance personnel, both in-house and contracted, must use the suitable work permits for performing tasks, including a hot work permit where necessary. A constant presence during the post work firewatch period is recommended. Mechanical repairs are favoured over welding repairs where possible, to avoid the possibility of damage to surrounding panels by sparks and heat.

- All electrical cables and components should be included in a formal maintenance contract. At least annually there should be a formal inspection of the condition of all electrical cables and connections, earthing cables and connections, junction boxes, DC conditioners and DC/AC inverters, plus auxiliary components such as fuses and switches. Thermographic testing of HV and LV equipment is recommended on a 6-monthly basis and connections should be checked for tightness.

- For roof mounted systems the roof should be inspected at least annually. Check the roof material for deterioration and peeling. Check that gutters are clear of debris. Safety barriers should be in good condition and firmly fixed in place. Roof construction such as chimneys should have no loose construction elements. The panel support structures should be firmly fixed in place and in good condition.

- The panels should be cleaned at least annually with clean water to remove surface dirt and salt. The frequency of cleaning can be gauged by trend analysis of the plant generating data.

Property Risks

The main risks of property damage are listed below:

- Impact damage due to hailstorm, falling objects or malicious damage.
- Damage by extreme weather – storm, snowfall, lightning strike.
- Electrical failure and overheating, caused by incorrect plant design, component corrosion, loose connections, extreme hot weather, temperature cycling fatigue etc.
- Theft
- Fire resulting from electrical damage, arson or fire spread from the building to the rooftop.

The electrical risks are mainly mitigated through adequate preventative maintenance of the system and components. This will include regular inspections, thermographic camera inspections and trend analysis of the system load to identify potential problems such as overloading and arcing.

Damage due to weather conditions should be limited as much as possible by the correct specification of components according to local weather conditions, based on historical data and natural catastrophe peril tools. This cannot fully mitigate all risks due to the random nature of natural perils, but the risk can be reduced to an acceptable level by probability.

Regarding the fire risks, the following points are recommended:

- For rooftop installations, all systems housed inside the building, such as inverters and switchgear, should be in a 1-hr fire-resistant room with automatic fire detection installed. Transformers should be physically or spatially separated.

- Wiring – particularly DC wiring that carries a higher current, should be limited as much as possible in length and consideration should be given to providing fire-resistance for cable runs that pass inside buildings.

- A remotely activated DC disconnection near the plant will help to prevent the risk of cutting through DC wires and also reduce the risk of arcing when panel arrays are wired in series but not yet connect to the grid. This facility, which should be clearly marked on the emergency plan, also gives the fire brigade confidence in using water on solar panel fires. However, even when disconnected the panels themselves are still energised during daylight hours and should be treated as live. Also, the capacitors in inverters can provide voltage for several minutes during daylight hours, on either side of a disconnect, even when opened. Covering the panels so that they stop the power generation would be effective, but a type of foam that adheres to the panel glass is not yet commercially available.

- The emergency plan of any commercial installation should include a list of responsible persons that can attend rapidly in the event of a fire, to assist the fire brigade in ensuring that the installations are disconnected and subsequently tensionless.

- For large commercial installations thought should be given to fixed fire protection. This would normally be in the form of gas suppression to cover the main electrical hazards, such as rooms housing inverters and switchgear, plus any rooms where batteries are used for power storage purposes.

Loss Expectancies

The size of a potential fire will be influenced by several factors including the size of the plant, the expected emergency response, the distance between modules (fire spread could be by thermal radiation or via cables), roof construction, vegetation for ground level systems, availability of fire-fighting water and preparedness of the emergency response team.

For roof mounted systems, a PV panel array provides a combustion risk on top of the roof. On a concrete roof this is unlikely to spread into the building except via openings and cable-penetrations. On combustible roofs a fire would quickly spread to the roof and then the spread via the roof itself would be more rapid than via the modules.

Theft losses account for a relatively high proportion of PV panel plant claims. Due to the difficulty in transporting the large panels, theft is often concentrated on the high-value and highly-portable copper cables. To help mitigate the theft risk, passive security measures that slow down potential thieves should be used in conjunction with active measures that ensure an emergency response to the site.

Losses due to malicious damage should also be taken into account. Loss history has shown that significant panel damage can arise through neighbouring farmers or residents unhappy that the plant was built on what was previously farmland, throwing stones and rocks into the plant to intentionally smash the panels.

A loss due to adverse weather conditions or natural catastrophe is more difficult to predict, but the size of such a potential loss can be limited mainly through the correct project planning and construction, taking into account local weather conditions, topography and natural catastrophe data for the area.

Business interruption should be taken into account following a fire or damage or failure of system components. Spare parts availability should be assessed, taking into account long lead-time parts and parts with a higher failure rate. Loss experience has shown that for commercial installations the business interruption costs account for approximately half of the total claim.

Previous losses in PV panel plants have given rise to some data trends that have enabled faulty components to be identified. This can be by batch or by manufacturer. Some components are known to have a relatively high failure rate, such as the junction boxes on the reverse side of the panels, which can be subjected to extreme temperatures. These factors should be taken into account during the project design and should be checked by the visiting Risk Consultant.

For roof mounted systems the overall increase in risk at the site due to the installation of the panels needs to be carefully considered by the visiting Risk Consultant. The risk of fire, theft and damage should be assessed against the good practice guidelines noted in this document, with recommendations for improvement made where necessary. The balance of the risk level versus the mitigating factors should be reflected in the overall site risk rating, as should the increased exposure risk at the site.

Disclaimer

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